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BULLETINS OF THE WEATHER BUREAU.

No. 1.—Notes on the Climate and Meteorology of Death Valley, California, by Mark W. Harrington, Chief of the Weather Bureau. June, 1892. (Octavo) 50 pp.

No. 2.—Notes on a New Method for the Discussion of Magnetic Observations, by Frank H. Bigelow, Professor of Meteorology. July, 1892. (Octavo) 41 pp.

No. 3.—A Report on the Relations of Soil to Climate, by E. W. Hilgard, Professor of Agriculture and Agricultural Chemistry, University of California. July, 1892. (Octavo) 59 pp.

No. 4.—Some Physical Properties of Soils in their Relation to Moisture and Crop Distribution, by Milton Whitney, Professor of Geology and Soil Physics, Maryland Agricultural College; Physicist, Maryland Agricultural Experiment Station; Fellow by Courtesy, Johns Hopkins University. August, 1892. (Octavo) 90 pp.

No. 5.—Observations and Experiments on the Fluctuations in the Level and Rate of Movement of Ground-Water on the Wisconsin Agricultural Experiment Station Farm and at Whitewater, Wis., by Franklin H. King, Professor of Agricultural Physics, University of Wisconsin; Physicist, Wisconsin Agricultural Experiment Station. December, 1892. (Octavo) 75 pp.

No. 6.—The Diurnal Variation of Barometric Pressure, by Frank N. Cole, Ph. D., Assistant Professor of Mathematics, University of Michigan. December, 1892. (Octavo) 32 pp.

No. 7.—Report of the First Annual Meeting of the American Association of State Weather Services. [Co-operating with the Weather Bureau, U. S. Department of Agriculture.] February, 1893. (Octavo) 49 pp.

No. 8.—Report on the Climatology of the Cotton Plant, by P. H. Mell, Ph. D., Professor of Geology and Botany in Alabama Polytechnic Institute; Director Alabama Weather Service. April, 1893. (Octavo) 68 pp.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU.

BULLETIN No. 9.

REPORT

ON THE

FORECASTING OF THUNDERSTORMS

DURING THE

SUMMER OF 1892.

BY

N. B. CONGER,
INSPECTOR, WEATHER BUREAU.

Published by authority of the Secretary of Agriculture.

WASHINGTON, D. C.:
WEATHER BUREAU.
1893.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., March 16, 1893.

SIR: I have the honor to transmit herewith a report on the "Forecasting of Thunderstorms during the Summer of 1892," by Mr. N. B. Conger, Inspector, Weather Bureau.

This work was carried out under the auspices of the State Weather Service Division of this Bureau, with the view of ascertaining whether or not it is feasible for the local forecast officials at the various State centers to forecast for their respective districts the occurrence of these severe secondary storms. This report shows the degree of success attained. I recommend that it be published as a Bulletin of this Bureau.

Very respectfully,

MARK W. HARRINGTON,
Chief of Weather Bureau.

Hon. J. STERLING MORTON,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,

Washington, D. C., February 28, 1893.

SIR: I have the honor to submit herewith my report on the investigation and forecasting of thunderstorms during the summer of 1892, a work to which I was assigned in May last, with station at Detroit, Mich.

There are also appended papers of similar purport by Messrs. Robert DeC. Ward, Cambridge, Mass., and Charles M. Strong, Columbus, Ohio, for their respective districts, New England and Ohio.

Very respectfully,

N. B. CONGER,
Inspector, Weather Bureau.

The CHIEF OF THE WEATHER BUREAU,

Washington, D. C.

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INVESTIGATION OF THUNDERSTORMS DURING THE SUMMER OF 1892.

INTRODUCTORY REMARKS.

The Chief of the Weather Bureau, desiring to have a practical study of thunderstorms made during the summer of 1892 to ascertain the feasibility of making thunderstorm forecasts and to obtain a better knowledge of their characteristics, began preparations for systematic work in this direction during the winter, and on April 1 the following circular was issued and sent to selected stations (named in the last paragraph of the circular), from whence they were issued to voluntary observers and others interested in this class of work, with a supply of record cards, for the purpose of rendering reports of storms occurring in their respective localities. In a few of the States the reports were numerous and well distributed, while in others there were very few reporters secured, and some of these reported for a short time only.

The following is a copy of the circular above referred to:

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., April 1, 1892.

THUNDERSTORM OBSERVATIONS.

The Weather Bureau desires to give special attention to the observation and investigation of thunderstorms and attending phenomena during the summer of 1892, and with this end in view the co-operation of meteorological observers and others interested is earnestly solicited. The object of this work is to gather material to be utilized in the study of these storms and the attending atmospheric conditions with a view to predicting the occurrence of this class of storms for special localities in time to make the forecast of value to agricultural interests. The great advantage of receiving information as to the actual prevalence of violent thunderstorms in certain quarters of your State, with reliable predictions as to when such a storm will likely reach your own community, should be apparent to all, and as there is no class of citizens which would not be benefited by a system that would make such work possible, there should be no difficulty in securing the voluntary assistance of observers in such numbers as to supply ample material for this work. Upon such voluntary co-operation on the part of observers the success of the plan will largely depend.

The field chosen for the proposed system of observations for the approaching season will embrace the region from the upper Mississippi eastward to the Atlantic coast, including the New England States, and if the results anticipated are realized, next year the territory will probably be extended to embrace the entire country.

For the purpose of recording observations postal cards have been prepared. These will be forwarded first to certain designated sub-centers, and later to the central office of the Weather Bureau at Washington.

For the guidance of those who desire to kindly assist in this work the following instructions are given:

Time.—Standard time, by which railroad trains are run, should be used in all cases. See that your watch is correct to within at least one minute.

Thunder.—Record should be made whenever a thunderstorm can be seen or heard. Thunder without rainfall should be noted, and in such cases care should be taken to state that no rain fell.

Movement.—The direction of movement of the storm should be carefully recorded; also any peculiar features of the movement, such as a dividing of the clouds.

Wind.—Direction should be given as shown by a vane on a high spire or building when possible. Take care that the north mark is correct. Record directions as N., NE., E., SE., etc., or if special care is taken, as N., NNE., NE., ENE., etc. The force of the wind may be described as calm, light, moderate, brisk, high, very high. A "very high" wind breaks limbs from trees and may do injury to some buildings. The time and direction of strong gusts or squalls are important.

Temperature.—The thermometer that is used should be as good a one as can be had. It should be hung out of doors in the shade, four or five feet above the ground, and over grass when possible. It should be freely open to the wind, but protected from the sun and rain; if near a house it should be on the north side, and not exposed to glaring reflections from white buildings or sandy roads. It is not necessary to estimate the fractions of a degree. The change of temperature accompanying a change of wind should be carefully noted.

Rain.—The time of beginning and ending of rain should be noted as closely as possible. The amount may be estimated as very light, light, moderate, heavy, very heavy, or the depth of rain may be measured as collected in a rain gauge. If the observer has no rain gauge a pail or can with vertical sides may be used, when the amount can be measured with a common rule. The amount of rain collected will often be less than one-tenth of an inch, and will seldom be more than one inch, unless the rain be long continued; its depth should be measured as soon as convenient after the rain ceases. When rain is seen falling in the distance it should be noted under "Remarks," as light rain to northwest at 4.25 p. m. The character of the rain, whether falling steadily or in brief showers, etc., descriptive notes of clouds, and any other fact worthy of special mention may also be noted under this heading.

Miscellaneous.—Photographic views of lightning flashes and thunderstorm clouds will be of special interest and importance, and are desired whenever it may be convenient to furnish them.

If you cannot take the observations above described will you be kind enough to give this circular to some one in your neighborhood who may be willing to do so?

When the space under "Remarks" proves insufficient for the report additional cards may be used, care being taken to date and number them in consecutive order.

Observations above referred to are desired only from May 1 to August 31.

Persons who may desire to act as thunderstorm observers in the several States will be furnished with postal cards and instructions, upon application to the observers of the Weather Bureau in charge of the central stations of their respective States, as follows: New England, Observer, Weather Bureau, Cambridge, Mass.; New York, Observer, Weather Bureau, Ithaca, N. Y.; Pennsylvania, Observer, Weather Bureau, Philadelphia, Pa.; New Jersey, Observer, Weather Bureau, New Brunswick, N. J.; Ohio, Observer, Weather Bureau, Columbus, Ohio; Michigan, Observer, Weather Bureau, Detroit, Mich.; Indiana, Observer, Weather Bureau, Indianapolis, Ind.; Wisconsin, Observer, Weather Bureau, Milwaukee, Wis.; Illinois, Observer, Weather Bureau, Springfield, Ill.; Missouri, Observer, Weather Bureau, Columbia, Mo.

MARK W. HARRINGTON,
Chief of Weather Bureau.

The following is a copy of the card record used by the thunder-storm reporters, on the reverse side of which is the address of the proper Weather Bureau official to whom it was sent:

Form No. 1077—Met'l.

Thunderstorm report.

U.S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

P.O., County, State,

Date of storm, 189...; Kind of time used,

Thunder.	First heard.	m.	Began...	m.	Began ..	m.	Highest wind.	Storm moved from
	Loudest ...	m.	Ended ..	m.	Ended ..	m.	Time m.	
	Last heard .	m.	Rain or snow.	Amount.	Hail.	Size	Direction.	..... to
Wind.	Before.	During.	After.				Force * ...	.....
	Direction.							
	Force * ...							
Temperature ..								

NOTE.—Under "Remarks" add such miscellaneous data as to loss of life or damage due to lightning; growth and movement of clouds; whether storm was moderate, severe, or violent.

* Wind should be expressed as calm, light, fresh, brisk, high, very high, tornado.

Remarks.	Only two cards left make () cross., Observer.
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GENERAL DISCUSSION.

The investigation of thunderstorms during the months of June, July, and August was conducted in the following States: Missouri, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York, New Jersey, and the New England States, and the comments made in this discussion are confined to this territory. Forecasts of thunderstorms were made by Weather Bureau officials at St. Louis, Mo., Chicago, Ill., Milwaukee, Wis., Indianapolis, Ind., Columbus, Ohio, Detroit, Mich., Pittsburgh, Pa., Albany, Buffalo, and New York, N. Y., Philadelphia, Pa., and New Brunswick, N. J. These stations had at least three sub-stations to the west of them which reported by telegraph the occurrence of thunderstorms between the hours of 8 a. m. and 6 p. m., except in a few cases where telegrams were sent at any time during the twenty-four hours, it being the intention to test the feasibility of making forecasts of thunderstorms on information received from the west.

The charts accompanying this report show the weather conditions over the United States east of the Rocky Mountain slope at 8 a. m. (Eastern standard time), and the thunderstorms which occurred during the day in the different sections of the above-mentioned territory.

These thunderstorms are represented on the charts in their movements and location by small arrows, flying in the direction in which the storm moved; the arrows with one feather represent the storms occurring between midnight and noon; arrows with two feathers rep-

resent the storms occurring between noon and midnight. It will be noticed that a large majority of these storms occurred during the afternoon or evening.

In this investigation it is only intended to bring out the salient points of the practical results of the season's work, and not to touch upon any theoretical point in the development of thunderstorms, and with this statement plainly outlined it will only be necessary to follow the attending thunderstorm conditions to prove: (1) that thunderstorms travel in well-defined areas from the Mississippi, (2) that sporadic thunderstorms exist which occur during heated terms and cover but limited territory, (3) that there is a relation to areas which pass to the eastward, (4) that there occur thunderstorms in districts which have been covered by previous storms on the same date, (5) that thunderstorms die out during the night and revive again the next day farther east, (6) and the feasibility of thunderstorm forecasting. In considering these different subjects several of the best authenticated types have been charted to convey a better understanding of their peculiarities.

The data have been compiled from a large number of card reports from correspondents in the territory named and have been condensed from separate State charts to one general chart for the entire district, together with the pressure and temperature lines at 8 a. m. of the same date.

The first subject to be considered is the movement of the thunderstorm areas from the west to east; there are several well-defined types of thunderstorm progressing steadily eastward, which will be noticed in order: On June 6, a thunderstorm belt was noticed in Wisconsin from 12.45 to 8 p. m., and while not reported in regular cadence in Illinois, was reported in Indiana at 1 a. m. of the 7th, and on the same date in Michigan from 2 to 5 a. m., and in Ohio from 2 a. m. to 2 p. m. In this area the regular progression was well defined. This area appeared to die out in Ohio. (See Chart I.)

On June 8 thunderstorm conditions were present in southern Michigan, northern Indiana, and Ohio; the general movement of the thunderstorms was to the northeast, while the belt appeared to spread to the southeast. The development of the belt began about 7 a. m. in northern Indiana and southern Michigan and moved in regular cadence through Ohio, reaching the southeast border at about 6 p. m.; the northeast portion of the storm moved into New York at 4.50 p. m. and died out by 7.45 p. m., before reaching central New York. Sporadic storms occurred later in the afternoon in Indiana. A secondary belt developed in Wisconsin from 6.45 a. m. to 11.15 a. m.; this belt was reported in southern Michigan at noon and progressed regularly across the State, reaching the eastern border at 5 p. m., where the record for the night lapses, but it appeared again at 11 a. m. of the

9th in western New York and moved steadily east, reaching the eastern border of the State at 4 p. m., and was reported in New England from 4.56 to 9 p. m., but its force decreased with its eastward movement. This thunderstorm belt will be again referred to in connection with thunderstorms occurring in a territory where a previous thunderstorm has occurred the same day, also in connection with thunderstorms dying during the night and reviving again the next day farther east.

The next well-defined type of thunderstorms, moving in regular progression from the west to the east, occurred on June 16, when thunderstorm conditions developed about 2 p. m. in Wisconsin and, traveling east, left the State about 5 p. m.; it was reported on the west shore of Michigan at 7 p. m., and extending south into northern Indiana, passed eastward, leaving Michigan at 11 p. m. The southwest portion of the storm area was reported in northeastern Ohio at 5.30 a. m. of the 17th and the area proper was noticed in western New York and Pennsylvania at 2.30 a. m. of the 17th, advancing steadily eastward, passed into Vermont at 10.30 a. m., and into Massachusetts and Connecticut a little after noon, and passed out of southeastern Massachusetts about 9 p. m. This is a well-developed type of the thunderstorms moving in regular progression from the Mississippi River to the Atlantic coast, and is authentically traced throughout the entire path. The thunderstorm belts of July 15 and 16 are also well-defined types of these thunderstorms. (See Charts II-V.)

The charts accompanying this report indicate the position of the pressure and temperature lines on these dates, so that it will not be necessary to trace the low areas with the movement of the thunderstorm belts. The fact that the weather conditions as shown on the chart at 8 a. m. are advancing eastward during the day should not be lost sight of, and that the storms occur during the afternoon—the change of base must be taken into consideration.

HEAT THUNDERSTORMS

This class of storms, which occur over a large territory without a definite path of progression and develop in the afternoon, is well illustrated in the series of storms which were reported from the Mississippi River to the Atlantic coast on July 26, during the height of the hot wave which prevailed at that period. In Wisconsin, Ohio, southern New York, and northern New England these storms occurred in the forenoon, while in Illinois, Indiana, Michigan, Pennsylvania, New York, and southern New England the thunderstorms occurred during the afternoon, and there appeared to be no connection between the storms of the East and those of the West. (See Chart VI.) The thunderstorm conditions of July 27 are indicative of the same class of storms and appear to have no progressive movement.

It is found that two distinct thunderstorm belts may traverse the same territory and that the second storm does not appear to hold its force to the same extent after it reaches the territory which has been covered by a previous storm on the same date. This is well defined in the thunderstorm belt of June 6.

It is noticed that thunderstorm belts, moving eastward during the day, appear to lose their identity during the night and revive again farther east the next day. This action is especially noticeable in the thunderstorm belts of June 8, when the trail disappeared at 5 p. m. in Michigan and was found at 11 a. m. the next day in New York, but with reduced force or activity, and advanced east. Prof. H. A. Hazen, in his report on thunderstorms in 1886, notices the same action in these storms, and remarks on their peculiarity.

Thunderstorm conditions are usually found on the southeast quadrant of a low area, and generally in the belt of pressure of 30.0 inches. (See Chart IV.) This is the class of storms which generally have the progressive movement to the east, and have approximately the same velocity as the low area. Thunderstorms also occur on the southwest quadrant of the low area, but these are more liable to occur in the afternoon and be sporadic in character. When two low areas are in progress the crest of the high between them is found to be a favored locality for the development of thunderstorm conditions. Prof. von Bezold, of the University of Berlin, in his memoir on thunderstorms in 1883, observes this and makes special note of it. Thunderstorms are sometimes developed on the northwest quadrant of a low area, but this was only noticed when the temperature changes were sharp and sudden in that section. Storms of this class are rare, of short duration, violent in action, and cover but a narrow path. Thunderstorm belts are occasionally developed in high areas when the weather conditions are of an unsettled nature, and a long trough of nearly normal pressure extends over a large territory to the north of the center of the high.

While there are no infallible rules to be laid down for forecasting thunderstorms from the daily weather charts, yet there are certain conditions, indicating the development of a thunderstorm belt, which generally follows during the succeeding twenty-four hours. A noticeable feature of the a. m. weather charts for this season was the relation of the thunderstorm belt to the pressure line of 30.0 inches and the thermal line of 70° . It is found that during the season nearly 90 per cent of the thunderstorms occurred in the belt covered by the isobar of 30.0 and at or near the isotherm of 70° . The presence of a low area to the west, moving in behind a high area, should be watched with great care as the thunderstorm conditions are very liable to develop during the afternoon or evening; the sharp curvature of the isobar, especially where it touches or crosses similar sharp curves of

temperature, has been found to be of value in forecasting. As before noted, thunderstorm conditions are generally found on the edges of low areas and are not reported in the centers, especially when the pressure decreases to 29.6 inches or below. When the thunderstorms occur on the southwest quadrant of a low area they are more liable to be sporadic in character, travel but a short distance, and soon die out; they represent a distinct type of thunderstorms and should not be classed with the thunderstorms which occur in the southeast quadrant of a low area.

In heated terms thunderstorms may be looked for along the line of change in pressure (30.0 inches) and where the temperature during the afternoon will continue high. These storm are more liable to occur the day after the maximum heat has passed. It is noticed during these periods that thunderstorm conditions are prevalent during the entire afternoon, and in many instances develop dry thunderstorms.

Where known thunderstorm belts exist to the west it is possible to forecast them for the territory farther east in the same manner as rain is now forecasted. The study of thunderstorms during this season has not established the fact that thunderstorms can be successfully forecasted for any specific locality, although with the aid of telephonic communication it has proved more feasible. The experiment of making forecasts on telegraphic warnings from stations to the west, some two hundred miles, has not proved of value as it appears that the belt may move rapidly in and cover the district with storms before the warnings can be issued to the public. With the warning coming from stations farther west, so that time may be had to issue the warnings to the public, it is considered that the method will meet with more success than during the season just passed.

In Michigan, where the telephone system was called into requisition, it was found to be of value in warning the public of approaching thunderstorms as the information was conveyed with great promptness over the telephone wires, and thus considerable time was saved. The State was divided into nine districts and each district had from three to six stations reporting to the section center, which reported direct to the central office at Detroit where the forecast was issued to the section where it was anticipated that the storm would occur during the day. If the storm was light the next station toward which the storm was moving was notified, and if it reached this section and appeared to be spreading the next contiguous section would then be notified. If the storm appeared to have considerable force the notice was sent into several sections at the same time. In many cases the warnings were issued from twelve to twenty-four hours in advance of the storm and must have been of considerable value to the general public as was evidenced by newspaper notices of the success of these forecasts. The telephone system was considered of no little value in

this line, and this success was due in a great measure to the prompt action of the Michigan Bell Telephone Company in handling these reports, a work which was admirably accomplished.

The forecasting of thunderstorms from the daily weather maps for the season was fairly successful. Of the forecasts issued from Columbus, Ohio, the percentages of verification were: For June 90 per cent, July, 86, August, 50, the falling off in August being due to the small number of storms which occurred during that month. In Michigan, where the telephone system was used, the following percentages are given: June, 86 per cent, July, 85, August, 78. It must be considered in this that an effort was made to forecast all thunderstorms, whether light or heavy, and not to forecast the severe storms only. In Mr. Robert DeC. Ward's paper, which accompanies this report, will be found a comparison of the Washington and Boston forecasts for New England, which indicates that the preliminary work in this line has been fairly successful.

With the particular types noted in detail on the a. m. weather charts, it is considered that with the history of the movement of these thunderstorm belts chronologically from June 1 to August 31, 1892, a sufficient knowledge has been gained to encourage the further prosecution of this very interesting study during the coming season over a more extended territory. To make this of value to the agriculturist in bringing out the facts on which forecasting may be better prosecuted, there should be a larger number of reporters in the several States where this investigation is to be pushed so that it will be possible to have a report of every thunderstorm that occurs in a State, as it was found that in several of the States the absence of these reports made it exceedingly difficult to accurately trace the thunderstorm belt from one State to another. Believing that generous assistance will be readily given when it is understood that this subject is being investigated for practical results, and to increase the value of forecasts in this line, there should be at least one reporter in every two or three townships in the State, as the erratic progress of the thunderstorm could then be accurately traced over the entire district.

The experience of the past season leads to the belief that the forecasting of thunderstorms is practicable, and with the assistance of those interested in this class of information it is believed that important results will proceed from the investigation of these storms during the summer of 1893.

BRIEF DESCRIPTION OF THE MORE IMPORTANT ATMOSPHERIC CONDITIONS WHICH PREVAILED DURING THE PERIOD OF THUNDER-STORM INVESTIGATION.

JUNE, 1892.

1st.—A low area was central over Missouri, moving northeast, with a second low central north of Lake Huron. Thunderstorms occurred in Indiana, Ohio, Michigan, New York, and Pennsylvania. Those in Indiana and Pennsylvania were scattered and local in character. The general movement of these storms was to the northeast, the majority of them occurring in the afternoon.

2d.—A low area moved into the St. Lawrence Valley, with the territory covered by thunderstorms lying on the south side from New England west to Ohio, with a few scattered storms in Michigan. In this case the storms lay grouped along the isothermal line of 70°. A high area lay on the Atlantic coast, moving slowly northeastward.

3d.—A few scattered storms in Pennsylvania, Ohio, and Indiana in the afternoon. A long trough of low pressure extended from Pennsylvania southwest to the Gulf. A high area was central over Lake Superior, with a low area developing in Montana.

4th.—The low area remains nearly stationary, with a pressure of 30.10 inches over the Lake region and the Ohio Valley; the temperature ranging from 60° to 70°. Thunderstorms occurred in the central Ohio Valley during the afternoon, mostly confined to the Lake Erie watershed.

5th.—The low area moved slowly northeast, with a high area central over western Michigan, and one of 30.20 inches on the south Atlantic coast. The thunderstorm belt moved during the night east into New York and Pennsylvania. A local thunderstorm occurred in southern Michigan during the afternoon. The general movement of these storms was to the northeast, but some few moved to the southeast and one in Ohio is noted as moving towards the north. The a. m. weather chart indicates that the force of the thunderstorm belt is rapidly decreasing.

6th.—The development of the low area in the St. Lawrence Valley produced a belt of thunderstorms in the New England States, but the conditions were feeble and but few storms occurred. The low area advancing from the west reached the Dakotas, and a belt of thunderstorms was reported in Wisconsin and Illinois. The majority of these storms occurred in Wisconsin on the southeast quadrant of the low area central over the Dakotas.

7th.—The low area moved over Iowa with a very little change in temperature lines. The belt of thunderstorms moved east into Ohio and Michigan, where they occurred during the early morning, while in Illinois, Indiana, and western Michigan they occurred during the afternoon.

8th.—During the night, the low area which was central over the upper Mississippi Valley filled up, and a pressure of 29.9 inches extended from the Dakotas to the Gulf of Mexico, with a high area of 30.2 inches on the south Atlantic coast. Thunderstorms were frequent during the afternoon in Ohio and eastern Michigan, and local storms in western New York and Pennsylvania, and in Illinois, Indiana, and western Michigan. The chart indicates a hot afternoon, and the storms appear to be moving from all directions, a characteristic of heat thunderstorms.

9th.—With the formation of a low in the Lake region over Michigan and general unsettled weather conditions, it was found that the thunderstorm belt had advanced east and was found extending west from New England to Indiana. In the States of Ohio, Michigan, Indiana, and Illinois the storms were scattered and of local character.

10th.—Feeble thunderstorm conditions existed in New York and Wisconsin. A low area was moving off the coast, pressure 29.9 inches, and a low of some energy, pressure 29.5 inches, was central over Colorado. Temperature slightly below the normal.

11th.—No storms reported.

12th.—Conditions very feeble, and only two storms reported in New York and one in Wisconsin.

13th.—With a low area central near Marquette and a secondary low over Kansas, thunderstorms were reported in Wisconsin, Michigan, Indiana, and Illinois during the afternoon, with a few local storms occurring in the forenoon in Wisconsin. The general direction of these storms was from the southwest to the northeast, although a few moved from the northwest to the southeast in Wisconsin. There was a high area lying on the south Atlantic coast and a very uneven distribution of temperature in the Eastern States, and on the west of the low area the temperature gradients were very sharp. The movement of the low area was eastward into the St. Lawrence Valley.

14th.—The belt of thunderstorms moved east with the low area and was found in New York, Pennsylvania, New Jersey, and the New England States. The low area at 8 a. m. was central near Rockliffe, Ontario. In southern Ohio, along the river westward to the Mississippi, there occurred thunderstorms from early morning in Illinois to late in the afternoon in Ohio. These storms all occurred near the change line of 30.0 inches and in the isothermal belt of 70°.

15th.—The low area passed off and disappeared during the night of the 14th. A high area in the Mississippi Valley, moving east, was replaced by a low area moving in from Montana. Scattered storms were reported from New York, Ohio, Indiana, and Wisconsin; conditions very feeble and not sufficiently developed to make note of.

16th.—A slight depression was central just east of Sault Ste. Marie,

extending southwest to Chicago, with a secondary low forming over Kansas. Temperature in the Mississippi Valley and lower Missouri Valley 80° and above. Thunderstorms occurred during the afternoon in southern Wisconsin, northern Illinois, and generally throughout Michigan. A few scattered storms occurred during the forenoon in Ohio, and general thunderstorms occurred in New York and Pennsylvania on the southeast quadrant of the low area central east of Sault Ste. Marie, while a high area covered the Atlantic coast, moving eastward.

17th.—The low area moved over the Missouri Valley and then took a northeasterly trend toward the Lake region. The high area is slowly moving off the coast. The isothermal line of 70° extended in an undulating curve from New England through New York, Ohio, Michigan, Indiana, Illinois, and thence southwest into Texas. Thunderstorms occurred in these States from the forenoon until late in the afternoon, but there seems to be no regular progression, and the separate storms moved but a short distance before they were exhausted. These storms were evidently caused by the heat wave that was passing at that time.

18th.—The low area remains stationary in the lower Missouri Valley, and east of this the pressure was about normal with a rain area extending from Kansas to New England. The pressure on the Atlantic coast being 30.2 inches. Thunderstorms were very frequent during the afternoon in Illinois, Indiana, southern Michigan, Ohio, western New York, and southern New England. A few scattered storms are noticed in Pennsylvania. The heaviest storms are reported in Ohio, southern Michigan, and northern Indiana and Illinois. The majority of these storms occurred in the afternoon, with a few scattered storms in the forenoon.

19th.—A few scattered storms occurred in New England and westward to Illinois. Two storms are reported on the upper Mississippi River at La Crosse and Red Wing; conditions feeble and the movement not well marked. Thunderstorms moved from the west to east. The low area passed northeast over the Lake region.

20th.—A low area of some magnitude developed during the night and was central at 8 a. m. over the St. Lawrence Valley, central pressure 29.5 inches; this area extended southwest into the lower Mississippi Valley and west to the Rocky Mountain slope, where a secondary low was forming. The thunderstorms were only reported in isolated places from New Jersey west to Illinois, and occurred in most cases about 2 p. m. There seemed to be no definite movement to these storms; they occurred at scattered points and died out before covering any extended territory.

21st.—The low area moved in from the northwest, and was central at 8 a. m. over Lake Superior. The isobar of 30.0 inches was south

of Ohio and east of the Mississippi River. Thunderstorms were frequent in southern New England, western New York, Ohio, Michigan, and Indiana, with scattered storms during the forenoon in Illinois. The temperature was not high in the south, nor were the gradients to the west steep. The storms moved from all directions, and appeared to occur simultaneously in all sections during the afternoon, except in western Indiana where they occurred in the forenoon.

22d.—A low was central over Colorado with a northeast movement, and a second low over the St. Lawrence Valley. The isothermal line of 70° extends from Boston west to Colorado, with thunderstorms along this line from New England to the Mississippi River; the general movement of these storms was from west to east, except in Ohio, where the storms have no general direction. The storms which occurred during the afternoon of the 21st in Ohio and western New York have advanced east, and occur during the forenoon in eastern New York and New England, and some portions of Pennsylvania..

23d.—The low remains stationary in the St. Lawrence Valley with a second low area moving in from New Mexico. The thunderstorm belt has moved into New England, and thunderstorms occur during the morning from eastern New York to eastern Massachusetts, and during the afternoon over entire New England, and occur sporadically west to Illinois during the day.

24th.—The low was slowly moving out of the St. Lawrence Valley, and the air pressure is returning to the normal conditions throughout the district. The last of the thunderstorms of the 23d are reported to-day in the northern portion of New England, while in portions of Pennsylvania, Ohio, Indiana, and Illinois a few scattered storms are reported, but the conditions are too feeble to show any decided movement.

25th.—During the night of the 24-25th the low area extended south over the New England States, and light local storms are reported in Vermont, New Hampshire, and eastern Massachusetts, and a few isolated storms in eastern Pennsylvania. The thunderstorms in New England occurred during the afternoon and had no regular progression.

26th.—Sporadic heat storms occurred in northern New England, and in Michigan, Illinois, Indiana, and Wisconsin. Those in New England occurred on the southwest quadrant of the low area moving out, while those in the West occurred on the southeast quadrant of the low area moving in during the day from the extreme southwest. These storms occurred late in the afternoon and during the evening. Heat entered to some extent into the formation of these, and the movement was not especially marked.

27th.—The low area moved in during the early morning, and was

central over Michigan at 8 a. m., with the east border over the New England States, and exhibited considerable energy, central pressure 29.5 inches. Thunderstorms occurred on the southeast quadrant of this low area from New England to Ohio, and had a general easterly movement, beginning early in the forenoon and extending late into the afternoon. In the Ohio Valley and New Jersey the storms occurred in the forenoon, while along the lakes they occurred from 1 p. m. to 3 p. m., and those in New England occurred somewhat later in the afternoon. The rainfall throughout this district was heavy, and the storms severe.

28th.—The low area moved over the St. Lawrence Valley, increasing in intensity, with a slight fall in temperature. These conditions would appear favorable for the formation of thunderstorms, but very few of them are reported, six in New England; and during the afternoon in Indiana, Illinois, Michigan, and Wisconsin a few scattered storms are reported. The movements of these storms were erratic and most of them occurred late in the afternoon or in the evening. A low area was forming in the Northwest, with an easterly movement during the evening.

29th.—The low area was central at 8 a. m. over Lake Superior, with a secondary low over Kansas, neither showing much energy. On the southeast quadrant of the low area central over Lake Superior, in New York and the New England States, thunderstorms occurred during the afternoon, and although not traced directly across, are evidently the same belt of thunderstorms that was noted in the Ohio Valley on the 28th, and developed again in the afternoon in New York and New England. The storms in New York had a general easterly movement, while those in Vermont moved from all directions. Late in the afternoon and in the evening thunderstorms occurred in southern Indiana and Illinois; storms feeble and the rainfall light. The temperature remains nearly stationary in all the districts.

30th.—This gives a fine type of thunderstorms progressing uniformly east with a low area. The low area moved east and was central at 8 a. m. over the St. Lawrence Valley, there having been a combination of the two lows during the night of the 29th, the area spreading to the southeast. Thunderstorms occurred during the early morning along the Ohio River, reached Pennsylvania about noon, spread over Pennsylvania, New Jersey, and New England during the afternoon, and increasing in force with the increasing heat of the afternoon. It is remarkable how closely the storms in this case followed the isothermal line of 70° which did not cross the isobars but lay more parallel to these lines. The rainfall in these districts was quite heavy at a majority of the stations.

JULY, 1892.

1st.—The low area having passed off the coast and a high area central over the Ohio Valley, with a slight fall in temperature, the conditions were not favorable for the formation of thunderstorms, and only a few are reported, and these are local in character. Thunderstorms are reported in Pennsylvania at 9 p. m., and at Ithaca, N. Y., in the forenoon and again in the afternoon; there are also noted four thunderstorms in northwestern Missouri, which are probably due to thermal conditions.

2d.—At 8 a. m. a low area was central over South Dakota, spreading southeast, with the temperature on the increase. The rain belt at this hour had extended southeast into Indiana and east into Wisconsin. Thunderstorms began during the forenoon in Missouri and extended during the afternoon as far east as southern Michigan and along the Ohio River to Parkersburg, W. Va. It will be noted that a majority of these storms occurred from 3 p. m. to 6 p. m., and at Detroit, Mich., began at 11 p. m. and extended into the morning of the 3d. The rainfall was unevenly distributed, and at some stations was very heavy (this is especially noted in Illinois), and to the east the rainfall was lighter. It would appear that the thunderstorm belt was general over the States of Indiana, Illinois, Michigan, and western Ohio at about 3 p. m., just after the maximum heat of the day occurred, and the movement east of the storm-center was about equal to the eastward movement of the thunderstorm belt. The general trend of these thunderstorms was from the southwest to the northeast; the low area moved southeast and was central over Illinois in the evening, moving slightly to the northeast.

3d.—The low area passed northeastward and was central at 8 a. m. over western New York, and extended to the Atlantic coast. The belt of thunderstorms moved east with the low area and the storms were continuous from early morning in Indiana to late in the afternoon in New England. The storms in New England developed about 3 p. m. This is probably one of the best type of thunderstorm belts moving steadily eastward in progression from the west to the east, the storm belt spreading out as it extended eastward, the low area maintaining its intensity with slight changes of temperature. The thunderstorm belt in this case appears to hold its identity throughout the night and during the day.

9th.—No thunderstorms were reported from the 3d to the 9th, and on the latter date with a high area dominating the Atlantic slope and the temperature nearly normal, there was a small rain area in New York and New England which developed into thunderstorms about 3 p. m. in southeastern New York and New England only. The movement of these storms was reported from all directions.

No thunderstorms were reported from the 9th until the 12th.

12th.—At 8 a. m. a low area moving in from the west was central near Duluth, Minn., and thunderstorms began about 2 a. m. along the upper Mississippi Valley and extended across Wisconsin and northern Illinois into Michigan late in the afternoon. A few isolated storms were reported during the afternoon in New York and New England. The belt of thunderstorms was forming during the afternoon in Illinois, Indiana, Ohio, and New York as the low area was passing east, and the conditions were exceedingly favorable for a large extension of the belt during the night.

13th.—The low area moved east and was central at 8 a. m. over the St. Lawrence Valley, with a central pressure of 29.8 inches. The thunderstorm conditions began to develop about 2 a. m. in Missouri and extended rapidly eastward, reaching Pennsylvania, New York, and New England late in the afternoon and evening. The general trend of the thunderstorms was from the southwest to the northeast. In this case it would appear practical to have telegraphed the warnings of these thunderstorms from Wisconsin or Illinois to New York and New England and have accomplished some very effective work, as the movement of the belt of thunderstorms was sufficiently regular to have the warnings issued in time to be of value.

14th.—The western edge of the low area passed off the Atlantic coast and the thunderstorm belt passed off during the afternoon. In Missouri, Iowa, and western Wisconsin local thunderstorms were reported during the day. A low area was central over Montana, moving southeast. The thunderstorm conditions were feeble in all the districts.

15th.—The low area was central at 8 a. m. over Lake Superior, with a central pressure of 29.7 inches. The belt of thunderstorms began at 2.25 a. m. at Kansas City, Mo., and extended east during the day, reaching Indiana and Ohio from 12 noon to 3 p. m., and was reported in New York and New England from 9 p. m. until after midnight. The rainfall was not heavy and the force of the storm light. The storms did not cover any extended territory in any of the States, except New York. The thunderstorms in southeastern New York about midnight moved into New England and were dissipated after traveling a short distance.

16th.—The low area moved down the St. Lawrence Valley, and the belt of thunderstorms which was noted to the west on the 15th is noted in New England only during the afternoon, and was passing out to sea.

No storms were reported on the 17th.

18th.—Local thunderstorms were reported from 5 a. m. to 7 a. m. in northwestern Missouri and northwestern Wisconsin. Storms light and did not cover any extended territory.

19th.—With nearly normal conditions throughout the entire district, and a low forming in the extreme northwest, thunderstorms were reported at Red Wing, Minn., in the morning, and in the afternoon in Michigan and Missouri. The movement of these storms was reported from the northwest, except in Missouri, where the movement was erratic. The storms were local in character and showed no particular force.

20th—Thunderstorms began to develop at Des Moines, Iowa, at 8.45 a. m. and extended southeast, reaching the Mississippi River at 11.30 a. m., Springfield, Ill., at 2.30 p. m., and Indianapolis, Ind., at 3.53 p. m., and moved into the southwest portion of Ohio during the afternoon. A local storm occurred at Columbus, Ohio, at 2.25 p. m., one and one-half hours before the storm reached Indianapolis. The trend of this belt of thunderstorms was from the northwest, and the path is well marked and the rate of progression defined. The low area was central in Montana, and stationary. The pressure throughout the district traveled by the thunderstorms was 30.1 inches, and the temperature in the seventies at the 8 a. m. observation. The rainfall at the beginning of the thunderstorm was very heavy and decreased in amount as the storm progressed eastward.

21st.—Local thunderstorms were reported along the Mississippi River from Davenport, Iowa, to St. Louis, Mo., and local storms in Ohio and northern Michigan. A low area was central over Lake Superior and a secondary low over Nebraska. The pressure over the States where these thunderstorms occurred was about 30.0 inches, and the temperature in the seventies. The thunderstorm conditions were feeble and the rainfall light.

22d.—The low area moved eastward and was central over the St. Lawrence Valley at 8 a. m. with thunderstorms located in Pennsylvania, New York, and New England during the afternoon and late in the evening. Local thunderstorms were reported in Michigan, Illinois, and Iowa. The storm in New York and some portions of New England was severe, and heavy rain and vivid lightning characterized the storm in southeastern New York. The storms occurring in the East were on the southeast quadrant of the low, while those in the West were on the southwest, and the latter were local in character.

23d.—Local thunderstorms were reported from the Atlantic coast west to Wisconsin, but were very few and were heat storms.

24th.—Thunderstorms were reported in western New York and Pennsylvania, in Ohio, Michigan, and Wisconsin, and were heat storms, as the conditions from the intense heat were very favorable for the formation of these storms. This was during the height of the hot wave, and thunderstorm conditions were present on each of the days of this heated term to a more or less extent. A remarkable cir-

cumstance is reported in Ohio during the afternoon—the thunderstorms began on the east border of the State, and spread west from 4 p. m. to 8 p. m., the progression being well defined. The storm in Michigan began in the extreme southwest portion and moved east, with heavy rain and destructive lightning. A low area was moving in from the west and was central at St. Vincent at 8 a. m.

25th.—The low area was central at 8 a. m. over Lake Superior, with the pressure below the normal throughout the Lake region. The heat wave still remains nearly stationary in the entire district, the thermal line of 80° covering a larger portion of the territory. These conditions make it very favorable for the formation of local thunderstorms on the southeast quadrant of the low area, and thunderstorms are reported from Indiana and southeastern Michigan east to the Atlantic coast. The thunderstorms occurred in the forenoon in New York and New England, and local storms in the afternoon in southern New England, Michigan, Ohio, and Indiana.

26th.—The heat wave has advanced to the east, and heat thunderstorms are reported from all sections, with no definite movement, the individual storms traveling but a short distance when they appear to die out. These storms occurred during the forenoon and afternoon, moved in all directions, were plainly indicated on the a. m. weather chart, and were to be anticipated from the intense heat which prevailed at this period. None of these storms had a progressive motion, but disappeared soon after their formation.

27th.—The low area moved south over Kansas, with a central pressure of 29.8 inches. The heat wave has moved slowly eastward, with local thunderstorms from New York west to Wisconsin. These storms were accompanied by heavy electrical discharges and heavy rainfall; there was no progressive motion noted in them.

28th.—The low area has moved over the St. Lawrence Valley during the day. Thunderstorms were reported late in the afternoon and in the evening in New England, New York, Michigan, Indiana, Illinois, Missouri, and Wisconsin. The storms in New England covered the whole district and have a distinct easterly trend, being on the southeast quadrant of the low area, while those of the West, on the southwest quadrant of the low area, were scattered and local in character, and had no general movement.

29th.—The low area was central over the St. Lawrence Valley, and the hot wave extended from the Lake region to the south Atlantic coast, with thunderstorm conditions reported from all districts, the storms being more severe along the Ohio Valley and northeast into New England. These storms occurred from 2 p. m. to 11 p. m., and were quite severe, accompanied by heavy rainfall in most cases. The storms occurred almost simultaneously throughout the district, and had no regular progressive motion.

30th.—Local storms were reported from along the Ohio River and in Pennsylvania and New Jersey, with one storm reported from New York. The low area has moved off the coast and a high area is central over Wisconsin and Michigan, with falling temperature.

31st.—A few local storms are reported in Wisconsin, Missouri, and New Jersey. The conditions were very feeble, and the storms did not travel over an extended territory. A low area was central over Lake Superior, with a slow eastward movement.

AUGUST, 1892.

1st.—A pressure of 30.0 inches covered most of the district this morning, and the temperature was nearly normal. A rain belt covered the majority of the territory and thunderstorms were developed in Illinois early in the morning along the Mississippi River; the storm was reported at Chicago at 12.57 p. m., and in Michigan from 1 p. m. to 5 p. m. in the State, and at 8.16 p. m. at Detroit, where the eastward movement appeared to have ceased. The second line of storms moved along the Ohio River; was at Springfield, Ill., 9.49 a. m., Indianapolis, Ind., at 5.21 p. m., and passed southeast into southern Ohio. A local storm occurred at Columbus, Ohio, at 12.13 p. m. The rainfall at the latter place was very heavy. The progression of this belt ceased in southern Ohio.

2d.—Local thunderstorms were reported at Baltimore, Md., and in southern New Jersey during the afternoon.

3d.—With a pressure of 30.0 inches and a temperature of 70° covering the district, with a rain belt confined to the lower Lake region and New England, thunderstorms were reported in northwestern Indiana and southwestern Michigan at 5 p. m. and moved east, reaching Detroit, Mich., at 8.10 p. m., where the progress east appears to have ceased for the night. Local thunderstorms were reported in Ohio. A low area began forming late in the afternoon and appeared to be concentrating over the St. Lawrence Valley.

4th.—The low area was central at 8 a. m. over the St. Lawrence Valley, and the thunderstorm belt which formed in northern Indiana, Ohio, and southern Michigan on the 3d was found in New York and New England, with local thunderstorms in eastern Pennsylvania. This belt appeared about 3 p. m., and covered the above-named States, and there appears a general easterly movement inclining slightly towards the northeast.

5th.—Although a low area was central over Lake Superior at 8 a. m., it is considered that the thunderstorms that occurred in Wisconsin from 5 a. m. to 7 a. m., in Illinois from 3 p. m. to 10 p. m., and along the Atlantic coast from noon until 5 p. m. were heat thunderstorms and not due to the location of the low area. The temperature was on the increase and the pressure nearly normal

throughout the district, and local causes evidently entered to a large degree into the formation of the thunderstorm conditions. This appears to be justified by the fact that a belt of thunderstorms is formed on the following day in New York, and the predominating cause was indicated by the heat of the afternoon. The low area contributed to the formation of the conditions, but the initial force appears to proceed from the increasing temperature.

6th.—A small belt of thunderstorms appears late in the afternoon in northern New York and New England, and are probably a portion of the same belt which was reported in the West on the 5th. Four local storms are reported in Missouri, but the conditions were very feeble, and soon disappeared.

7th.—A local thunderstorm was reported at St. Louis, Mo., at 2.25 a. m. and lasted until 2.50 a. m., with heavy rainfall; this storm was again reported in eastern Illinois late in the afternoon, indicating that thunderstorm conditions were present, but not strong enough to develop a general storm.

8th.—Thunderstorms were reported during the morning in Iowa, Wisconsin, Michigan, and Ohio. Those in Wisconsin illustrate a clear type of regular progression of heavy thunderstorms with uniform velocity over an extended track. This belt was first reported in St. Croix County, on the west border of Wisconsin, at 1.40 a. m., and traveled eastward at the rate of 47 miles per hour, and reached Manitowoc County, on the eastern border of the State, a distance of 236 miles, at 7 a. m. It was nine times observed in regular succession across the State, and each moment of arrival was in regular cadence to establish the eastward movement of 47 miles per hour. This storm was reported in central Michigan at 1.45 p. m., and reached the eastern border late in the afternoon, with greatly diminished force, simply indicating that the thunderstorm conditions were present but feeble.

9th.—With a low area extending from the St. Lawrence Valley to Lake Superior, thunderstorms were reported in the morning and afternoon in New York, New England, New Jersey, Ohio, Michigan, Indiana, Illinois, Missouri, and Wisconsin. A clear type of the progressive thunderstorm is exhibited in a series of thunderstorms which occurred during the afternoon in Michigan. The thunderstorms began about 3 p. m. in the extreme southwestern portion and moved northeast across the State and passed out at 6 p. m. The storms in Wisconsin and contiguous States occurred later than did those in the Eastern States. The storms in New York and New England were attended by heavy rain and vivid lightning.

10th.—A low area, central pressure 29.8 inches, covered northern Michigan at 8 a. m., with a hot wave on the southeast quadrant, extending along the south Atlantic coast. Thunderstorm conditions

began to develop about 1 p. m. in Missouri and Illinois; at 2.30 p. m. in northern Indiana and southern Michigan, and from 2 p. m. to 10 p. m. in Pennsylvania, New York, New Jersey, and New England. These latter storms were evidently heat storms, as they occurred throughout the district simultaneously and moved from all points of the compass. A series of thunderstorms began in southwestern Michigan about 1 p. m., and moved regularly northeast, reaching Port Huron, Mich., at 4 p. m., and was regularly observed at seven stations in the path during its progress.

11th.—The low area moved east over the St. Lawrence Valley, with the hot wave lying stationary on the Atlantic coast. Scattered thunderstorms were reported during the forenoon in Missouri, Illinois, and Ohio. In Pennsylvania, New Jersey, New York, and New England heavy thunderstorms were reported from 1 p. m. to 10 p. m. The main feature of these storms was the presence of the hot wave over this district, which assisted materially in the formation of the thunderstorm conditions. As is characteristic of heat thunderstorms there was no regular eastward movement, each storm appearing to take an individual path and die out after traveling a short distance.

12th.—Local thunderstorms occurred in Massachusetts, Connecticut, and Rhode Island during the afternoon, and there does not appear any progressive motion.

No storms of note are reported from the 12th until the 18th.

18th.—A low area was central at 8 a. m. over Lake Superior, moving east. A thunderstorm belt was developed at St. Louis, Mo., at 2.20 p. m., was reported twice in Illinois, and reached Chicago, Ill., at 10.08 p. m. Several light thunderstorms were reported in western Michigan from 8 p. m. to 10 p. m., indicating the presence of the thunderstorm belt moving east.

19th.—The low area moved over the St. Lawrence Valley and moved out during the day; a high was central over Minnesota, with a pressure throughout the district of 30.05 inches, and the temperature about 70°. Thunderstorms occurred from 6.10 a. m. to 11.50 a. m. in Michigan and Ohio, and in the afternoon in Pennsylvania, New York, and New England. A local storm occurred in the afternoon in Indiana. These storms had a general easterly movement, except in New England, where they appeared to come from the northwest and move southeast. These latter storms appear to be largely affected by local causes.

20th.—Thunderstorm conditions were reported in New England, Iowa, and Missouri. They were local in character and the conditions feeble.

21st.—Thunderstorm conditions were reported east of Cincinnati, Ohio, along the river, and in eastern Pennsylvania and New Jersey

in the afternoon from 1 p. m. to 2.30 p. m. These storms were entirely local in character.

23d.—Local thunderstorm conditions were present during the afternoon in western Missouri. Rainfall light and the thunderstorm conditions feeble.

24th.—During the night of the 23d-24th a low area moved over Missouri and was central near St. Louis, Mo., at 8 a. m., and extended northeast. Thunderstorm conditions were reported at Red Wing, Minn., at 11.45 a. m., but were not reported to the east in Wisconsin; at St. Louis, Mo., at 11.05 a. m., Springfield at 5.23 p. m., Cairo, Ill., at 3.22 p. m., Cincinnati, Ohio, at 10.50 p. m., Columbus, Ohio, at 6.41 p. m., Sandusky, Ohio, at 8.25 p. m., and in Michigan from noon until midnight in different portions of the State. Three local storms were reported in New York.

25th.—The thunderstorm belt of the 24th moved east and was found on this date during the afternoon and evening in New York, Pennsylvania, New Jersey, and New England, with heavy rain in the different localities, and the thunderstorms severe. The general movement of these storms was from the west to east, although in the mountains of Pennsylvania their movement was diversified.

This is the last general thunderstorm condition that was reported during the season, which closed August 31, 1892. A few local storms occurred but were not of sufficient importance to warrant charting.

INVESTIGATION OF THUNDERSTORMS IN NEW ENGLAND, BY MR.
ROBERT DEC. WARD, CAMBRIDGE, MASS.

The object of this investigation being "to gather material to be utilized in the study of these storms and the attending atmospheric conditions, with a view to predicting the occurrence of this class of storms for special localities in time to make the forecast of value to agricultural interests," particular attention has been paid to the verifications of the Washington and Boston forecasts during the summer of 1892 as far as the prediction of thunderstorms is concerned. In obtaining the percentages of verification the forecasts have been considered fully or partly verified when *rain, showers, local showers, showers accompanied by thunder, thunder showers, or thunderstorms*, were predicted for the region, or for some part of the region, where thunder showers fell, and for the time in which they fell.

The thunderstorms have been divided into two classes, (1) those which showed distinct progression when charted, and (2) those which did not move but appeared only as scattering reports. In obtaining the verifications of the forecasts only those storms have been considered which moved, as this is the only class which is likely to do damage, and is also the only class of which warning that the storm is on its way may be given by telegraph or by telephone, and whose conditions of occurrence therefore need special attention. The thunderstorms that do not show movement are usually very limited in extent, and are generally little more than thunder associated with light showers. These classes may be further subdivided according to the conditions under which the storms occur, and in this subdivision the writer recommends, with one change, the classification* given by Prof. W. M. Davis, who says:

There appear to be four classes of summer thunderstorms, apart from those nondescripts whose features are lost in the far-reaching clouds of a general storm. The first class are those of local origin on quiet, hot, anticyclonic days, their action suggesting that they are merely overgrown convectional movements. * * * These are less common than the others. A second class includes those which spring up in the warm southerly winds southeast of a cyclonic center, and whose convectional overturning is therefore due in part to imported heat. * * * Such storms are also relatively rare. The third class includes the largest of our summer thunderstorms. These seem to be formed where the warm southerly winds are most nearly contrasted with the cooler westerlies that follow them. The storm forms along the line between the two and advances obliquely, broadside across country. * * * The fourth class of thunderstorms contains those which arise in the westerly winds, southwest of a cyclonic center, and whose convectional overturning is due as much to the importation of cool air aloft as to its warming on the ground below.

* Annals of the Astronomical Observatory of Harvard College, Vol. XXI, Part II, pp. 131-132.

The change recommended by the present writer is the addition of a fifth class, to include "those nondescripts whose features are lost in the far-reaching clouds of a general storm." The characteristics of thunderstorms which occur under such conditions, in a general rain, are sufficiently distinct to warrant their being put in a definite class by themselves. The storm of May 3-4 may be taken as a good example of this proposed fifth class. These storms are seldom severe or destructive; they are not distinguished by marked changes in wind direction, although the squall-wind is generally noted at a few stations; hail seldom falls; the temperature is usually nearly stationary, and the rain is apt to continue after the thunderstorm itself has passed on, the thunder and lightning generally being accompanied by a somewhat heavier rainfall than is noted before or after the thunderstorm proper.

May.—During May thunderstorms were reported on the 2d, 3d, 4th, 9th, 11th, 12th, 16th, 17th, 26th, 27th, and 30th, but on three days only did the storms have distinct progression, viz., on the 3d-4th, 26th, and 27th. These latter, which all occurred in general rains, were predicted in the Washington and Boston forecasts both at 8 p. m. of the days previous and at 8 a. m. of the days of occurrence. They occurred southeast of the cyclonic centers on those days.

June.—In order to summarize the thunderstorms and forecasts in June as briefly as possible, Table I has been prepared. The first column gives the day of the month; in the second is a statement whether or not any observers reported, and if they did so the number of reports received is given; the third column states whether or not the thunderstorms had progression; the fourth gives the time, and the fifth the place of occurrence; in the sixth the intensity of the storms is noted (moderate, severe, violent); in the seventh column are the Washington, and the eighth the Boston forecasts, so much of them as relates to precipitation.

It appears from Table I that thunderstorms were reported on every day except the 4th, 5th, 7th, 8th, 10th, and 11th, that is, on twenty-four days. On thirteen days the storms had distinct movement; on the remaining eleven days there were generally very few reports and no progression could be made out, the records being scattered and not agreeing as to times of rain beginning and loudest thunder. As regards the verification of the forecasts the following results were obtained. The Boston forecasts not including Connecticut, the forecasts made for June 18, on which day a thunderstorm occurred in that State only, have not been considered. Taking the twelve remaining days on which progressive thunderstorms occurred, it is seen that the Washington 8 p. m. forecasts of the evenings previous were verified fully or partly in six, and were wrong in six cases, and the corresponding Boston forecasts were verified in nine and were

wrong in three cases. Of the 8 a. m. forecasts on the thunderstorm days, the Washington forecasts were right in eight and failed in four cases; the Boston forecasts were verified in ten and were wrong in two cases. On the 2d the Washington 8 a. m. forecast has been considered wrong, as it predicted local rains in the evening, which means after 8 p. m., and on the 16th the Boston 8 a. m. forecast has been considered right, because it predicted showers on Friday the 17th, which began as a forecast day at 8 p. m. of the 16th.

It appears, therefore, that warning was given of the thunderstorms of June (either as *thunderstorms* or as *showers*) in the local forecasts issued at 8 p. m. of the days previous or at 8 a. m. of the same day, in ten cases, leaving two cases where no warning of any kind was given. In four cases *thunder showers* were predicted at 8 p. m. of the days previous, and in three more cases they were predicted at 8 a. m. of the days on which the thunderstorms occurred, and on three other days *showers* were predicted. There seems to have been no attempt made at Washington to predict *thunderstorms* as such, as in only one case was a thunderstorm successfully predicted, but as several of the display stations in New England receive the Washington forecasts it has been thought best to obtain the verifications of the Washington in the same way as in the case of the local forecasts. Every forecast of *thunderstorms*, *thunder showers*, or *showers probably accompanied by thunder* made at Boston during the month was verified.

As regards the conditions under which the thunderstorms of this month occurred, an examination of the 8 a. m. maps of the thirteen days on which progressive storms were noted brings out the following facts: On seven days the cyclonic area was over the Lakes; on two over the Gulf of St. Lawrence; on two over New England; on one over the Lower St. Lawrence, and on one day anticyclonic conditions prevailed, with pressure above the normal. The most violent thunderstorms occurred on the 14th and 17th, both of which days were marked by trough-shaped isobars to the southwest of the cyclonic center. The main features of the maps on these days are the general high temperatures over New England, being considerably above the normal in most cases; the occurrence of local showers or thunderstorms in the Lake region during the preceding twelve hours; conditions favorable for showers over New England during the following twelve hours; southerly or westerly winds; a cool wave south of the Lakes, and indications of a secondary depression over or to the west of New England in some cases. The main features of the 8 p. m. maps of the evenings previous are in general similar to those just enumerated, the distinguishing characteristics, in addition to these, being the position of the cyclonic center farther to the west in most cases, and the general rise of temperature over New England since the last observation.

Of the seventeen days in June on which no progressive thunderstorms occurred, ten had a pressure near or above normal, generally clear or fair and mostly cool, anticyclonic weather; four had cyclonic centers over the Lakes, the Gulf of St. Lawrence, or New England, with general rains or showers over the district, accompanied by thunder at a number of stations, but bringing no progressive thunderstorms, and on three days the pressure was near or above normal, with no definite center, and showers, accompanied by thunder at some stations, fell in parts of New England.

July.—It is seen from Table II that thunderstorms were reported during July on every day but the 1st, 4th, 7th, 16th, 17th, 20th, 21st, 27th, and 30th, that is, on twenty-two days. The thunderstorms showed distinct progression on nine days only; on the remaining thirteen days there were generally few reports, five days giving but one report on each day, one day giving two, and one day three reports, and the other six days bringing scattered reports of very moderate storms. Considering again, as in the case of June, only the progressive storms, it appears that the Washington 8 p. m. forecasts of the days previous to the occurrence of the thunderstorms were fully or partly verified in six cases, and were not verified in three cases, and the corresponding Boston forecasts were fully or partly verified in six, and wrong in three cases. Of the 8 a. m. forecasts on the nine days during which the thunderstorms occurred, the Washington were fully or partly verified in seven and not verified in two cases; the corresponding Boston forecasts were verified in eight cases, and not verified in one case. There being no 8 a. m. forecasts on July 3, which was Sunday, the Saturday 8 p. m. forecast has been used in calculating the verifications.

From Table II it will be seen that warning was given of the *rain* of these nine days, either in the Boston 8 p. m. forecasts of the preceding days or in the 8 a. m. Boston forecasts on the thunderstorm days, in every case. *Thunder showers* were predicted in the Boston forecasts at 8 p. m. of the days previous in two cases, and at 8 a. m. of the storm days in two more cases, and in the remaining five cases *showers* or *rain* were predicted. The Washington forecasts also gave warnings, either of *thunder showers* or of *rain*, in every case, when both 8 a. m. and 8 p. m. forecasts are reckoned. The Boston forecasts predicted no thunderstorms when such storms did not occur. The Washington forecasts predicted them in one case when they did not occur.

The 8 a. m. weather maps of the thunderstorm days show the following characteristics as to pressure: Cyclonic centers over the Lower St. Lawrence in three cases; over the Upper Lakes in two cases; over the Lower Lakes in two cases; over the Gulf of St. Lawrence in one case, and in the remaining case there was no well-defined

center of low pressure. The further features were high temperatures over New England, in some cases unusually high; showers during the preceding twelve hours in the Lake regions, and generally a cool wave following over the Lakes or west of them. There were thirteen days on which thunderstorms were reported and showed no movement. These days were generally characterized by anticyclonic conditions of weather, with pressure above the normal. Two of them had moderate cyclonic areas over the Lakes or the Gulf of St. Lawrence, with high temperatures over New England, and it is to be noted that both of these days brought several reports of thunderstorms, though no movement can be made out. The no-thunderstorm days show either anticyclonic conditions or cyclonic areas over the Lower St. Lawrence or over the Gulf of St. Lawrence. In the latter cases clearing, cooler weather had already set in over New England, and the forecasts were for fair weather. The small number of distinct thunderstorms during July was evidently due to the fact that the anticyclones of the month were more marked and of longer duration than the cyclones, and, although they were less in number than the latter, they controlled the weather during the greater part of the month.

August.—During the month of August, as will be seen from Table III, thunderstorms were reported on all days but the following: 1st, 2d, 7th, 8th, 15th, 16th, 17th, 18th, 22d, 23d, 24th, 28th, 29th, and 30th. They were therefore recorded on seventeen days during the month. On nine of these days they showed progression across country, viz., on the 4th, 5th, 6th, 9th, 10th, 11th, 12th, 19th, and 25th. On the remaining eight days on which thunderstorms were reported they do not seem to have moved more than a very few miles, and no rain-front lines can be drawn. Of these days, two brought one report only, two brought two reports only, and of the remaining four days, two brought less than ten reports and one brought fifteen reports. It is seen from this that on those days when the thunderstorms did not have distinct progression the reports were very few in number. They were also scattered, and the local storms, often merely thunder without rain, to which they referred, were very moderate in character.

Coming now to the forecasts for the nine days with distinctly progressive thunderstorms, we find that the Washington and Boston 8 p. m. forecasts of the days previous were fully or partly verified in seven cases, and were not verified in two cases. Of the 8 a. m. Washington and Boston forecasts on the thunderstorm days, eight were fully or partly verified and one was not verified. It appears that warning was given of the precipitation on the nine thunderstorm days in the Boston forecasts in every case. *Thunderstorms or thunder showers, or showers with thunder*, were predicted in the Boston forecasts

of the evenings preceding the nine distinct thunderstorm days in two cases, and in the morning forecasts of those days in three more cases, and in the remaining four cases *showers* or *local rains* were predicted, without mention of thunder. The Washington forecasts also covered the precipitation which came on these thunderstorm days in every case. The Boston forecasts gave no predictions of *thunderstorms*, *thunder showers* or *showers accompanied by thunder* which were not verified, fully or partly. The Washington forecasts predicted *thunder showers* for New England on two days only, and in each case the prediction was verified.

The nine days which brought distinctly progressive thunderstorms show the following characteristics as to pressure: Cyclonic centers over the Lower St. Lawrence in three cases; over the Gulf of St. Lawrence in two cases; over the Upper Lakes in one case; over the Lower Lakes in two cases, and off the New England coast in one case. The connection of thunderstorm occurrence with centers of low pressure is thus again clearly brought out, and also it is seen that the isobars were trough-shaped in several cases, notably on August 5th, 6th, and 19th, on all of which days severe thunderstorms occurred. The characteristics of these maps are, further, conditions favorable for rain and high temperatures over New England, and showers and lower temperatures in the Lake region during the preceding twelve hours. The maps of the eight days on which scattered thunderstorms or thunder were reported, but on which no distinct movement was noted, show the following characteristics: Pressure normal or above normal, and usually rising, temperatures considerably lower than on the distinct thunderstorm days (about 10°), with conditions favorable for showers, but closely followed by clearing weather in six cases and fair weather in two cases. The distinction between these two sets of maps is therefore quite clear. The maps of the remaining no-thunderstorm days show a striking similarity in their features, viz., pressure above the normal; temperatures lower than on thunderstorm days; fair, anticyclonic weather, and northerly or northeasterly winds. In a few cases there was a cyclonic center over the Gulf, moving off to the northeast. It is seen, therefore, that the conditions of thunderstorm occurrence were quite distinct through this month.

TABLE I.—*Summary of thunderstorms and forecasts for the New England States during June, 1892.*

Date.	Thunderstorms reported.	Time of occurrence.	Place of occurrence.	Intensity of storms.	Washington forecasts.	Boston forecasts.
1	Yes... (1)	No ... 9-10 p. m...	Me.....	Moderate.....	8 a. m. Fair weather, increasing cloudiness, and probably local showers Thursday night. 8 p. m. Fair weather, followed by cloudiness and local rains and probably thunderstorms.	8 a. m. Fair. 8 p. m. Fair, followed during the late afternoon or night by showers, probably accompanied by thunder at places. 8 a. m. Continued warm and fair.
2	Yes... (10)	Yes ... 1.30-6 p. m...	Vt., N. H., Mass., Conn.	Moderate.....	8 a. m. For Me., fair weather. For N., H., Vt., Mass., Conn., and R. I., increasing cloudiness and local rains this evening and Friday. 8 p. m. Partly cloudy weather and showers Friday.	8 p. m. Showers, probably accompanied by thunder. 8 a. m. Rain, probably followed by clearing to-night or Saturday morning. 8 p. m. Fair, cooler.
3	Yes... (3)	No ... p. m	N. H., Conn	Moderate.....	8 a. m. Some cloudiness and occasional showers. 8 p. m. For Me., N. H., and Vt., generally fair. For Mass., R. I., and Conn., generally fair Saturday, except some cloudiness and local showers on the coast.	8 a. m. Fair. 8 p. m. For R. I. and Mass., warmer and fair, except showers are probable in the afternoon. For Me., N. H., and Vt., warmer, partly cloudy and showers.
4	No .....	.....	.....	.....	8 a. m. Generally fair weather..... 8 p. m. Generally fair weather..... 8 p. m. Partly cloudy weather and possibly a few showers, mostly along the coast Monday.	8 a. m. Fair, preceded by thunder showers this afternoon. 8 p. m. Fair.
5	No .....	.....	.....	.....	8 a. m. For Me., N. H., and Vt., fair weather, except possibly showers in northwest portions to-night. For Mass., R. I., and Conn., fair weather.	8 p. m. Fair and cooler.
6	Yes... (52)	Yes ... 1-5-30 p. m...	E. Mass., E. Conn., and R. I.	Moderate.....	8 p. m. Generally clear weather..... 8 a. m. Fair weather..... 8 p. m. Fair weather..... 8 a. m. Generally fair weather..... 8 p. m. Me., N. H., Vt., cloudiness and showers. Mass., R. I., Conn., cloudiness and scattered showers.	8 a. m. Fair, cooler. 8 a. m. Fair, slightly warmer. 8 a. m. Fair, warmer.
7	No .....	.....	.....	.....	8 a. m. Partly cloudy and showers..... 8 p. m. Partly cloudy and showers..... 8 a. m. Some cloudiness followed by generally clear weather and possibly preceded by showers along the coast from Nantucket to Sandy Hook.	8 a. m. Cloudy and showers. 8 p. m. Partly cloudy and showers. 8 a. m. Fair, cooler.
8	No .....	.....	.....	.....	8 a. m. Partly cloudy and showers..... 8 p. m. Partly cloudy and showers..... 8 a. m. Some cloudiness followed by generally clear weather and possibly preceded by showers along the coast from Nantucket to Sandy Hook.	8 a. m. Cloudy and showers. 8 p. m. Partly cloudy and showers. 8 a. m. Fair, cooler.
9	Yes... (52)	No ... p. m	S. and SE. Mass., N. Conn., R. I.	Moderate.....	8 a. m. Partly cloudy and showers..... 8 p. m. Partly cloudy and showers..... 8 a. m. Some cloudiness followed by generally clear weather and possibly preceded by showers along the coast from Nantucket to Sandy Hook.	8 a. m. Cloudy and showers. 8 p. m. Partly cloudy and showers. 8 a. m. Fair.
10	No .....	.....	.....	.....	8 p. m. Generally fair.....	8 p. m. Fair.

11	No . . . . .	.....	8 a. m. Fair.....	8 a. m. Fair, warmer.
12	Yes... No . . .	3-5 p. m . . .	8 p. m. Fair.....	8 p. m. Fair, warmer.
13	Yes... (11)	6-7 a. m., 4-6 p. m.	8 p. m. Continued warm and fair.....	8 p. m. Fair, except local thunder showers during the afternoon.
14	Yes... (218)	12 m-9 p. m. Me., N. H., Vt., Mass., R. I., and Conn.	8 a. m. Continued very warm and clear weather	8 a. m. R. I. and Mass., fair, except local thunder showers Tuesday afternoon. Me., N. H., Vt., fair, except local thunder showers.
15	Yes... No... (1)	1 a. m. R. I.	8 p. m. Fair weather	8 p. m. Fair, except local thunder showers in the afternoon.
16	Yes... (35)	6-30-10 p. m. N. Vt., N. H., Me., Mass., and Conn.	8 a. m. Continued fair; possibly local showers	8 a. m. Fair, followed by thunder showers to-night or Wednesday.
17	Yes... (86)	10 a. m.-6 p. m. (except in N. H., N. H. (except in N.), Vt., Mass., R. I., and Conn.)	8 a. m. Violent; much damage.	8 p. m. Much cooler, clearing and fair weather.
18	Yes... (32)	1-30-5-30 a. m.	8 a. m. Moderate.	8 a. m. Wednesday night.
19	Yes... (3)	p. m.	8 p. m. Moderate.	8 a. m. Fair.
20	Yes... (7)	No....	8 a. m. Moderate.	8 p. m. Fair.
21	Yes... (59)	Early a. m. N. H., Mass., and R. I. and p. m. R. I.	8 p. m. Moderate.	8 a. m. Clear.
22	Yes... (22)	3-5 p. m . . .	8 p. m. Central and SE. Mass., N. and E. Conn., and R. I.	8 p. m. Fair.
23	Yes... (77)	8-10 a. m. Conn., Me., N. H., and Vt.	8 p. m. Moderate.	8 a. m. Showers
		1-5 p. m . . .	8 p. m. Moderate.	8 a. m. Showers on the coast; generally fair in the interior.
				8 p. m. Local showers, followed by clearing weather.
				8 p. m. Fair, cooler; rain Thursday night or Friday.
				8 p. m. Light rains, showers, followed by clearing weather.

TABLE I.—*Summary of thunderstorms and forecasts for the New England States during June, 1892—Continued.*

Date.	Thunderstorm reports.	Time of occurrence.	Place of occurrence.	Intensity of storms.	Washington forecasts.	Boston forecasts.
24 (24)	Had pro gress.	No....	6-8 p.m....	N.H., Vt., Me., and Conn.	Moderate.....	8 a.m. Me. and N.H., showers. Vt., fair. Mass., R.I., and Conn, fair on Saturday, preceded by showers, followed on the coast.
25 (49)		Yes...	12 m-4 p.m.	NE. Mass., and S. N. H.	Moderate.....	8 p.m. Showers, followed by fair.....
26 (23)		No....	2-5 p.m....	Vt., S. N. H., and Mass.	Moderate.....	8 a.m. Me., N.H., and Conn., showers to-day, fair Sunday.
27 (20)		Yes...	5-8 p.m....	Vt., N.H., W. Mass., and SW. Conn.	Moderate.....	8 p.m. Me., N.H., and Conn., showers, followed by fair Sunday.
28 (12)		No....	Early a.m.	Me., N. H., Mass., and R.I.	Moderate.....	8 a.m. Showers to-day; fair Wednesday.
29 (47)		Yes...	6-7 p.m., 10-12 p.m.	Vt., N.H., and Mass.	Moderate.....	8 p.m. Showers to-day; fair Wednesday.
30 (165)		Yes...	1-5 p.m.	Vt., N. H., S. Me., Mass., and Conn.	Moderate; generally severe in Conn.	8 a.m. Rain.

TABLE II.—*Summary of thunderstorms and forecasts for the New England States during July, 1892.*

Date,	Time of occurrence,	Place of occurrence,	Intensity of storms,	Washington forecasts,	Boston forecasts,
1 No....	.....	.....	.....	8 a.m. Me., N. H., and Vt., generally fair. Mass., R. I., and Conn., local showers.	8 a.m. Fair.
2 Yes... (2)	No....	p. m.....	Vt.....	8 p.m. Me., N. H., fair. Vt., fair; rain by Sunday morning. Mass., fair. R. I. and Conn., fair; local showers on coast.	8 p.m. Fair.
3 Yes... Yes... (137)	Yes... Yes...	12-30-6 p.m..	Me., N. H., Vt., and Conn.	8 a.m. Fair; showers on Sunday.....	8 a.m. Fair.
4 No.... No....	No.... No....	a. m....	Vt.....	8 p.m. Increasing cloudiness and rain.....	8 p.m. Increasing cloudiness followed by rain.
5 Yes... (1)	Yes... No....	.....	Vt., N. H., Mass., and R. I.	8 p.m. Showers; clearing during Monday.....	8 p.m. Fair.
6 Yes... (26)	Yes... No....	.....	.....	8 p.m. Fair.....	8 a.m. Fair.
7 No....	.....	.....	.....	8 a.m. Fair.....	8 p.m. Fair.
8 Yes... (59)	No....	p. m.....	S. N. H., Vt., Mass., Conn., and R. I.	8 a.m. Fair.....	8 a.m. Fair.
9 Yes... (39)	No....	a. m. and p. m.	Me., Vt., N. H., and W., Conn.	8 a.m. Fair; preceded by local showers in southern portion. Mass., R. I., and Conn., generally fair Sunday, probably showers Sunday evening or night.	8 a.m. Fair, except scattered local showers during the afternoon.
10 Yes... (1)	No....	p. m.....	Vt.....	8 p.m. Local showers, followed by clearing weather.	8 p.m. Fair; showers, followed by clearing weather.
11 Yes... (1)	No....	p. m.....	Vt.....	8 p.m. Fair.....	8 p.m. Fair.
12 Yes... (13)	No....	p. m.....	Vt., Mass., R. I., and Conn.	8 a.m. Fair; Wednesday afternoon or night. Mass., R. I., and Conn., fair.	8 a.m. Fair, probably followed by showers Wednesday.
				8 p.m. Me., N. H., Vt., R. I., and Mass., fair.	8 p.m. Fair.
				8 a.m. Me., N. H., Vt., and Mass., fair. Wednesday afternoon or night. Mass., R. I., and Conn., fair.	8 a.m. Fair, probably followed by showers Wednesday.
				8 p.m. Me., N. H., Vt., and Mass., fair, followed by local showers during the afternoon or night. R. I. and Conn., fair.	8 p.m. Fair, followed during the afternoon by local thunder showers.

FORECASTING OF THUNDERSTORMS.

TABLE II.—Summary of thunderstorms and forecasts for the New England States during July, 1892—Continued.

Date.	Thunderstorms reported.	Time of occurrence.	Place of occurrence.	Intensity of storms.	Washington forecasts.	Boston forecasts.
13	Yes... (128)	Yes...	2:30-7:30 p.m.	N. H., Vt., Mass., and Conn.	Moderate.....	8 a.m. Me., N. H., Vt., and Mass., local showers. R., I., and Conn., fair. Showers, followed by clearing weather.....
14	Yes... (32)	Yes...	4-12 p. m...	Me., N. H., Vt., E. Mass., N. Conn., and R., I.	Moderate.....	8 a.m. Fair.....
15	Yes... (122)	Yes...	11:30 p. m.- 4 a. m. of 16th.	S. Me., N. H., Vt., Mass., R., I., and Conn.	Severe till 12 p. m., then moderate.	8 p.m. Fair.....
16	No....	No....	.....	.....	.....	8 a.m. Me. and N. H., increasing cloudiness, with showers during Friday night or Saturday, Vt., local showers, followed by clearing weather. Mass., N. H., and Vt., showers, probably beginning this afternoon. Thunderstorms are likely to accompany showers.
17	No... (1)	No...	8:20 p. m...	Me.....	Moderate.....	8 p.m. Showers and severe local storms.....
18	Yes... (3)	No...	a.m. and 2:30 p. m.	Me. and Vt.	Moderate.....	8 a.m. Fair.....
19	Yes... (3)	No...	.....	Thunder only ..	Moderate.....	8 a.m. Fair.....
20	No....	No....	.....	.....	Thunder only ..	8 a.m. Fair.....
21	No....	No....	.....	.....	Thunder only ..	8 p.m. Fair.....
22	Yes... (22)	Yes...	2 p.m.-11:30 p. m.	S. Me., N. H., Vt., Mass., and Conn.	Moderate.....	8 a.m. Fair.....
23	Yes... (22)	No....	Early a. m. and p. m.	E. Me., Vt., SE. Mass., E. Conn., and R., I.	Moderate.....	8 p.m. Me., N. H., and Vt., clearing, generally fair. R., I., and Conn., occasional thunderstorms, but generally fair during the day.
24	Yes... (14)	No....	Late p. m...	N. H., Vt., and Mass.	Moderate.....	8 p.m. Fair, probably followed by local thunderstorms during the afternoon or night.

25	Yes... (78)	Yes...	2.30 a. m.- 4.30 a. m.- 2.30 p. m.- 7 p. m.	Me., N. H., Vt., Mass., Conn., and R. I.	Moderate.....	8 a. m. Me., N. H., and Vt., fair, probably followed by local showers Tuesday or Tuesday night. Mass., R. I., and Conn., fair, with local showers in Mass., by Tuesday night.	8 a. m. Fair, except occasional local show- ers and thunderstorms.
26	Yes... (61)	Yes...	1 a. m.-3 a. m.- 9 a. m.- 10-30 a. m., p. m.	Me., N. H., Vt., Mass., R. I., and Conn.	Moderate.....	8 p. m. Fair..... 8 a. m. Me., N. H., and Vt., local showers..... 8 p. m. R. I., and Conn., generally fair. 8 p. m. Me., N. H., and Vt., fair. Conn., generally fair, possibly local thunder- storms by Wednesday night.	8 p. m. Generally fair. 8 a. m. Fair, occasional showers due to ex- cessive heat. 8 p. m. Generally fair.
27	No.....	.....	.....	.....	.....	8 a. m. Generally fair..... 8 p. m. Me., and N. H., fair, Vt., showers during the afternoon or night. Mass., and R. I., increas- ing cloudiness, with local thunderstorms dur- ing the afternoon or night.	8 a. m. Fair, followed Thursday night or Friday by local thunder showers.
28	Yes... (140)	Yes...	4 p. m.-10 p. m.	N. H., Vt., Mass., Conn., and R. I.	Moderate.....	8 a. m. Me., and N. H., fair, except showers in N. H., and southern New England, Vt., local show- ers to-night or to-morrow. Mass., R. I., and Conn., local showers to-day or to-night. 8 p. m. Me., N. H., and Vt., local showers, except in eastern Me., fair weather. Mass., R. I., and Conn., increasing cloudiness, probably local showers Friday afternoon or night.	8 a. m. Fair, except showers are likely this afternoon and night in northern parts of Me., N. H., and Vt.
29	Yes... (156)	Yes...	2 p. m.-11 p. m.	Me., N. H., Vt., Mass., R. I., and Conn.	Moderate gen- erally, severe in places.	8 a. m. Increasing cloudiness, probably followed by local showers during Friday night or Satur- day. 8 p. m. Me., N. H., and Vt., showers. Mass., R. I., and Conn., local rains.	8 p. m. R. I., fair. Mass., Vt., and N. H., showers during the day. Me., showers during the afternoon.
30	No.....	.....	.....	.....	.....	8 a. m. Me., N. H., and Vt., clearing to-day on the coast. Mass., R. I., and Conn., on Sunday fair weather.	8 a. m. Fair, except showers to-day for coast sections.
31	Yes... (1)	No...	p. m	Conn	Thunder only ..	8 p. m. Local showers to night..... 8 p. m. Mass., R. I., southern N. H., and Vt., northern N. H., and northern Me., gen- erally fair.	8 p. m. Generally fair, except cloudiness and some rain on the extreme southern New England coast.

TABLE III.—*Summary of thunderstorms and forecasts for the New England States during August, 1892.*

Date.	Thunderstorms, reports.	Time of occurrence.	Place of occurrence.	Intensity of storms.	Washington forecasts.	Boston forecasts.
1	No.....	.....	.....	.....	8 a.m. Me., N. H., and Vt., showers on the coast to-day; fair to-night. Mass., R. I., and Conn., showers to-day; fair to-night.	8 a.m. Cloudy and unsettled, probably occasional rains along the coast.
2	No.....	.....	.....	.....	8 p.m. Generally fair.	8 p.m. Generally cloudy on the coast and partly cloudy in the interior, probably followed by light local rains during the night.
3	Yes .. (2)	No.....	p. m.	Conn ..	8 a.m. Me., N. H., and Vt., fair, followed in southern portions by showers to-night. Mass., R. I., and Conn., showers followed by clearing weather.	8 a.m. Cloudy, probably light rains for the southern coast sections.
4	Yes .. (70)	Yes ..	4-8:30 p. m.	Me., N. H., Vt., Mass.	8 p.m. Rain, followed by fair weather.	8 p.m. Continued rainy, probably followed by clearing during the afternoon or evening.
5	Yes .. (67)	Yes ..	p. m.	Me., N. H., Vt., Conn.	8 a.m. Fair, preceded to-day by showers on the coast	8 a.m. Fair, preceded by coast showers to-day.
6	Yes .. (51)	Yes ..	2-6 p. m.	Me., N. H., Vt., Mass.	8 p.m. Generally fair.	8 p.m. Fair.
7	No.....	.....	.....	.....	8 a.m. Fair, except showers this afternoon evening in northern parts of Me., N. H., and Vt.	8 a.m. Fair, preceded by local rains except in R. I.
8	No.....	.....	.....	.....	8 p.m. Fair, except showers in N. H., and Vt., to-night.	8 a.m. Generally fair.
9	Yes .. (108)	Yes ..	a.m. and p. m.	Me., N. H., Vt., Mass., R. I., and Conn.	8 a.m. Clearing to-day; fair to-night.	8 a.m. Partly cloudy, followed during the afternoon by showers, probably attended by thunder.
					8 p.m. Showers in northern portion and on the coast.	8 a.m. Fair, preceded by showers to-day on the Maine coast.
					8 p.m. Showers in northern portion and on the coast; clearing to-night.	8 p.m. Fair.
					8 p.m. Fair.	8 p.m. Fair.
					8 a.m. Showers in northern portions, Mass., R. I., and Conn., fair, probably preceded to-day by showers on the coast.	8 a.m. Fair, followed by increasing cloudiness and rain Wednesday night or Thursday. Mass., R. I., and Conn., fair, preceded by showers to-night in eastern Mass., rain Wednesday night or Thursday.
					8 p.m. Fair, followed by thunder showers during the afternoon or evening.	8 p.m. Fair, except local showers or thunderstorms are probable during the afternoon or night.
					8 p.m. Fair, followed by increasing cloudiness and rain Wednesday night or Thursday.	8 p.m. Partly cloudy weather and showers.

10	Yes . . . Yes . . . (70)	3:30-5 a.m., p. m.	Me., N. H., Vt., Mass., R. I., and Conn.	Generally moderate; severe in Vt. and N. H.	8 a.m. Me., N. H., and Vt., fair, followed in northern portions by showers to-night or Thursday. Mass., R. I., and Conn., fair.	8 a.m. Continued fair weather, except thunderstorms and local showers are likely this afternoon and night.
11	Yes . . . Yes . . . (108)	2-9 p. m.	Me., N. H., Vt., Mass., R. I., and Conn.	Severe.	8 p.m. Showers	8 p.m. Showers.
12	Yes . . . Yes . . . (48)	12:30-2 a.m., 5-7:30 p.m.	Me., N. H., Vt., Mass., R. I., and Conn.	Violent.	8 a.m. Me., N. H., and Vt., thunder showers to-day and to-night. Mass., R. I., and Conn., thunder showers to-day, clearing to-night. 8 p.m. Me., N. H., and Vt., showers, followed by clearing by Friday night. Mass., R. I., and Conn., showers clearing by Friday night.	8 a.m. Continued fair, except thunderstorms and local showers are probable this afternoon or night.
13	Yes . . . No. . . . (7)	p. m.	N. H., Mass., Conn., and R. I.	Very moderate.	8 a.m. Me., N. H., Vt., rain, clearing by Saturday night. Mass., R. I., Conn., showers, followed by clearing Saturday.	8 a.m. Fair, preceded to-day in coast and southern sections by showers.
14	Yes . . . No. . . . (12)	Early a.m.	Mass.	Thunder only.	8 p.m. Me., N. H., and Vt., fair, except showers in northern portions. Mass., R. I., and Conn., fair.	8 a.m. Fair, except showers in parts of Vt., N. H., and Vt.
15	No.	8 a.m.	Mass.	Thunder only.	8 p.m. Me., N. H., and Vt., fair, except showers in northern portions. Mass., R. I., and Conn., fair.	8 p.m. Fair, except local showers in parts of Vt., N. H., and Vt.
16	No.	8 a.m.	Mass.	Thunder only.	8 p.m. Me., N. H., and Vt., fair, except showers in northern portions. Mass., R. I., and Conn., fair.	8 p.m. Fair, except local showers in parts of Vt., N. H., and Vt.
17	No.	8 a.m.	Mass.	Thunder only.	8 p.m. Me., N. H., and Vt., fair, followed Thursday night by showers in northern portions. Mass., R. I., and Conn., fair.	8 a.m. Fair, except showers in parts of Vt., N. H., and Vt.
18	No.	8 a.m.	Mass.	Thunder only.	8 p.m. Me., N. H., and Vt., fair, followed in northern portions by showers to-night or Friday. Mass., R. I., and Conn., fair.	8 a.m. Fair, except showers in parts of Vt., N. H., and Vt.
19	Yes . . . Yes . . . (65)	p. m.	N. Vt., S. N. H., N. Mass., and Conn.	Severe in Vt. and Mass., elsewhere moderate.	8 a.m. Me., N. H., and Vt., showers in Me., Saturday day and in N. H., and Vt., to-night. Mass., R. I., and Conn., increasing cloudiness and showers.	8 a.m. Fair, except showers may occur in northern sections to-night.
20	Yes . . . No. . . . (15)	Early p. m.	N. H., Vt., Mass., and Conn.	Moderate.	8 p.m. Showers	8 p.m. Showers.
21	Yes . . . No. . . . (11)	p. m.	S. Conn.	Thunder only.	8 a.m. Me., N. H., and Vt., showers to-day. Mass., R. I., and Conn., showers to-day; clearing in the interior to-night.	8 a.m. Cloudy, probably light rain for some of the coast sections to-day.
22	No.	8 p.m.	Mass.	Thunder only.	8 p.m. Fair, preceded by showers on the coast to-night.	8 p.m. Generally fair.

FORECASTING OF THUNDERSTORMS.

TABLE III.—*Summary of thunderstorms and forecasts for the New England States during August, 1892—Continued.*

Date.	Thunderstorm reports. Had progress.	Time of occurrence.	Place of occurrence.	Intensity of storms.	Washington forecasts.	Boston forecasts.
23	No....	.....	.....	.....	8 a.m. Me., N. H., and Vt., increasing cloudiness and showers in northern portions to-night or Wednesday. Mass., R. I., and Conn., fair.	8 a.m. Fair.
24	No....	.....	.....	.....	8 p.m. Me., N. H., and Vt., increasing cloudiness; showers in northern portions by Wednesday night. Mass., R. I., and Conn., fair, except showers in western Mass.	8 p.m. Fair.
25	Yes .. (16)	Yes ..	9-10 p.m. .	Mass. and W. Conn..	8 a.m. Me., N. H., and Vt., showers in northern portions to-day; showers Thursday. Mass., R. I., and Conn., showers in western Mass. to-night or to-night; showers Thursday.	8 a.m. Generally fair to-day, favorable to local rains to-night and to-morrow.
26	Yes .. (8)	No....	Early a.m..	Mass. and R. I.	8 p.m. Me., N. H., and Vt., showers and thunderstorms. Mass., R. I., and Conn., showers and probably thunderstorms.	8 p.m. Increasing cloudiness, followed by rain.
27	Yes .. (1)	No....	p.m.	Me ..	8 a.m. Me., N. H., and Vt., showers and probably thunderstorms to-day. Mass., R. I., and Conn., thunderstorms to-night; clearing Friday.	8 a.m. Rain, probably thunderstorms during the evening or night.
28	No....	.....	.....	.....	8 p.m. Me., N. H., and Vt., showers, followed by clearing in northern portions. Mass., R. I., and Conn., showers.	8 p.m. Mass., and R. I., rain, followed during the day by clearing weather. Me., N. H., and Vt., rain.
29	No....	.....	.....	.....	8 a.m. Me., N. H., and Vt., clearing in northern portions to-day, and in southern portions to-night. Mass., R. I., and Conn., clearing to-day or to-night.	8 a.m. Clearing during the evening or night.
					8 p.m. Me., N. H., and Vt., fair, preceded to-night by showers in N. H. and Vt. Mass., R. I., and Conn., showers.	8 p.m. Mass., and R. I., cloudy and some rain. Me., N. H., and Vt., local showers in Vt., but generally fair.
					8 a.m. Me., N. H., and Vt., fair in northern, showers in southern portions. Mass., R. I., and Conn., showers to-day, clearing to-night or Sunday morning.	8 a.m. Cloudy, threatening, rain along the coast, clearing to-night for southern sections.
					8 p.m. Me., N. H., and Vt., showers, followed by clearing weather.	8 p.m. Clearing and fair weather; preceded by rain during the early morning in Me.
					8 p.m. Fair.	8 p.m. Fair.
					8 a.m. Fair.	8 a.m. Fair, probably rain by Tuesday night.
					8 p.m. Fair.	8 p.m. Fair, except local showers during the afternoon or evening in Vt.

39	No.....	.....	.....	8 a. m. Me., N. H., Vt., fair, followed Wednesday by showers in northern portions. Mass., R. I., and Conn., fair.	8 a. m. Unsettled, rain probably beginning during the evening or night.
31	Yes .. (4)	No.....	p.m	SE. Mass., S. Conn., and R. I.	8 p.m. Generally cloudy, followed during the evening or night by rain.
				Moderate.....	8 p.m. Showers
				8 p.m. Showers	8 a. m. Unsettled, probably light rains to-day and to-night.

CONCLUSION.

From the accompanying tables and summary the status of the Washington and Boston forecasts regarding the thunderstorms of the summer has been made clear, and in presenting this result the chief object of this report has been attained. It must be confessed that the interpretation of the verifications has been very liberal, but still the fact stands out quite plainly that the percentage of success was high. It was intended, at the beginning of the summer's work, to make arrangements for having telegraphic reports sent to Boston from a few stations on the western border of Massachusetts and Connecticut whenever a distinct thunderstorm passed over the observers there. The hope was that such a scheme, tried throughout one or two months, would show whether this is practicable on a larger scale, the object being to determine whether or not some such plan, systematically carried out, might not make more definite thunderstorm forecasts possible by the sending out of special telegrams from the Boston office, giving warning of approaching storms. This plan was not put into operation for several reasons, but the experience of the summer has shown that it would have been of little use. In the first place, if a thunderstorm passed over a single station, or even several stations on the western border, it would be difficult to tell whether it was going to extend so as to cover all, or a part, of New England, or was soon to fade away, traveling only a few miles. Secondly, the time consumed in sending the telegraphic reports to the Boston office and from there out again to other stations would be so long that the thunderstorm, if it were moving across country at the usual rate, would have reached most of the towns before the telegram from Boston could be received. This plan is therefore deemed impracticable.

Another plan, first suggested some twenty or more years ago, seems to have a good deal to recommend it. It is, briefly, this: Whenever any observers on the western borders of, in this case, Vermont, Massachusetts, and Connecticut, note the passage of a thunderstorm over their place of observation, they shall at once telegraph or telephone the fact to other places farther east, and that from these latter stations the warning should be sent on still farther east, and so on. At every place where such a warning is received, flags should be hoisted or whistles blown, according to some definite prearranged scheme, to inform the people of the fact that a thunderstorm is on its way. It is believed that this method would be the best one, and indeed the only practicable one, for giving distinct warning of approaching storms by telegraph or telephone. The advantages to be gained from it would be greatly increased if warnings could be received from stations in New York State whenever thunderstorms pass over them moving in an easterly direction. Such a plan, systematically arranged in the spring and carried out through the sum-

mer, would, it is believed, be of great benefit to farmers. One of the difficulties in making it successful is the lamentable lack of trained observers in New England. A trained observer can, in many cases, tell whether a thunderstorm at his place of observation is merely a local one, or is part of one of the larger disturbances, which often extend over several hundred miles and may be expected to travel across the districts north and south, as well as east of him. To give warning to stations farther east in *every* case where a thunderstorm passes over any place would very soon bring the whole scheme into ridicule.

Considering the success attained in the forecasts during the summer, it is believed that the first step to benefit agricultural interests at present should be towards a greater extension of the display stations of the New England Weather Service. The increase in the number of these stations during the past year has been very rapid, and at present the forecasts are scattered broadly over all the New England States, but the further extension of this work, by sending out more telegraphic and telephonic forecasts, and by the establishment of more display stations, would, it is evident, be of great and direct benefit, both in disseminating the forecasts in general, and the thunderstorm forecasts in particular. In this direction the Weather Bureau has a field of work which cannot fail to be productive of great good to the farmers of New England.

It has been seen, as was to have been expected, that the local forecasts made at Boston attained a somewhat higher degree of accuracy than those made at Washington. This, combined with the additional fact that the Boston forecasts are made and sent out from half an hour to an hour before the Washington forecasts are received at Boston, makes it plain that the interests of the Weather Service work in New England would be best furthered by the distribution of the local forecasts.

The majority of the voluntary observers kept faithful records throughout the summer, but their inexperience in such matters, which they frankly acknowledge, necessarily impairs the value of the reports. The latter serve well enough to determine the main facts of the extent and progression of the storm, and of the changes in wind direction and temperature, but the data as to amount of rainfall and direction of movement of the storms have generally been disregarded, on the ground that they are unreliable. The careful measurement of rainfall is a difficult task, and the crude means necessarily adopted by the observers make it plain that the amounts registered are in most cases too inaccurate for quotation. The rainfall records have, however, served very well to give a general idea of the amount of rain, whether heavy or light. As to direction of movement, the records differ very greatly, observers near together often giving exactly contrary directions. For this reason, and because the determination of the

movement of a thunderstorm from each place of observation by itself is very difficult, this portion of the records has generally been disregarded. The space devoted to "Remarks" on the blanks was very small, but several observers made good use of it. The most noteworthy remarks have been quoted in the preceding pages, and some of them show careful and interested attention on the part of the observers to the storms to which they refer. The most valuable notes on the thunderstorms of the summer are those from Prof. W. M. Davis in connection with the storms of June 14 and 17, but many of the others, quoted in the descriptions of the several storms, are worthy of attention, especially those from Mr. Wm. C. Appleton on July 29, from Newburyport on June 14, and those describing the ending of a storm on August 4. But little attention is given to cloud observations. A few simple records of the growth and movement of the thunderstorm clouds would give valuable results, and it is believed by the writer that careful attention to this subject would help greatly in a full discussion of the theory of thunderstorms. Further, each observer, by noting the growth and movements of the thunder clouds, can, with a little practice, make tolerably accurate forecasts for himself of the approach of thunderstorms. To this end the movement of the overflowing cirrus cover, which usually runs an hour or more ahead of the storm, should be carefully noted; for it appears from the study of these storms so far that they seldom occur unless there is a cirrus overflow from the top of the general cumulus cloud mass. In this direction there seems to be an attractive and a useful line of work.

The materials at hand at present are not sufficient for a complete discussion of the general theory of thunderstorms in relation to the thunderstorms of New England, and therefore this portion of the subject is deferred to a later date. It may, however, be stated here, that, as has been seen, the great majority of the thunderstorms of New England occur in the southeastern, southern, or southwestern octants of cyclonic centers central over the Lakes, the Lower St. Lawrence, or the Gulf of St. Lawrence. This clearly shows that their convectional overturning is generally due partly to the imported warmth brought in the warm southerly winds of the cyclonic circulation and not only to the warming due to local insolation. They do occur on hot, anticyclonic days, but less frequently, and the storms under such conditions are usually small affairs, of moderate character, and only move a few miles. They have been well described in the reports several times, the observers noting their beginning as an ordinary cumulus cloud of small size, which gradually grows upwards and soon brings rain, with moderate thunder and lightning. The storm is usually noted as of small extent north and south, and as fading away after an hour or less.

The data from one summer's investigation are of course too few to give any reliable averages. A few general facts may, however, be noted here. The majority of the thunderstorms of New England have their origin outside of this district, and come to it ready-made from the West; they are mostly large disturbances, covering many miles, in several cases two or three hundred miles, and move in a systematic way in an easterly direction. The lines showing the positions of the rain-front at successive hours and half-hours usually run in a NE.-SW. direction, which gives the storm, when charted, the appearance of a southeasterly movement. It is believed, however, that the storms usually move in a more easterly or even northeasterly direction, but sidle along, as it were, their broad rain-front extending from northeast to southwest. This gives them practically a south-easterly movement. The convex rain-front lines, which are a general characteristic of thunderstorms, are clearly brought out in several of the charts.

With regard to the classification of the storms, according to progression and non-progression, adopted in this report, it may be stated, as already mentioned above, that the storms which do not show distinct movement across the country and which cannot be charted on the general plan herein adopted, are generally moderate and local in character, and seldom do damage. It has already been seen that the days on which thunderstorms were reported, but on which no movement can be made out, bring only few and scattered reports. The hours of maximum frequency during the summer were 4-8 p. m.; the average velocity was a little less than 30 miles an hour.

One of the notes most frequently made in the records is on the dividing of the storms before they reached the observer. Indeed, almost every storm during the summer was noted as dividing at one or more stations. With reference to this phenomenon it may be said that it is very likely that the small local storms, which last but a short time, can be, and are often, influenced by the topography of the country, that is, by the mountains and river valleys. It does not seem possible, however, that the larger storms which ascend thousands of feet into the atmosphere, which may move several hundred miles, and which cross the White and Green mountains and the Berkshire Hills apparently without any change in their movement, can be influenced by small isolated hills or river valleys. The account given by the observer at Dublin, N. H., confirms this point, at least as far as that station is concerned. He says that Mount Monadnock causes the smaller storms to divide every time they come to it from the west, and that the two parts go northeast and southeast, respectively, leaving, as he reports, Dublin in the center of two rainy belts, without a drop of rain there. This dividing, he says, happens only when the storms are small, and when their northern

and southern limits can be seen. In the case of larger and more severe storms, whose limits can not be seen, the mountain has no effect.

Many cases of the apparent effect of topography can undoubtedly be explained by the fact that when an observer sees a thunderstorm coming from the west he expects it will pass over him, no matter what the direction of movement of the storm. If the storm does not move over the observer, but in its regular course moves northeast or southeast of him, he is very apt to attribute this to the influence of neighboring hills or valleys. Another very common belief is that certain districts are more exposed to damage by thunderstorms, including lightning and hail, than others near by. This point is an interesting one for further investigation, but at present no definite statement can be made with regard to it.

In presenting this report the writer feels that it by no means contains all the results that can be obtained from the data collected during the summer of 1892, but it does bring out some of the main facts concerning the thunderstorms of New England, and as a preliminary contribution to further work when more data are at hand it cannot fail to be of value.

ROBERT DEC. WARD.

HARVARD UNIVERSITY,

CAMBRIDGE, MASS., *March 1, 1893.*

REPORT ON THUNDERSTORMS IN OHIO DURING THE SUMMER OF 1892, BY MR. CHARLES M. STRONG, OBSERVER, WEATHER BUREAU, COLUMBUS, OHIO.

COLUMBUS, OHIO, October 22, 1892.

SIR: I have the honor to submit herewith a report on thunderstorms in Ohio during the months of June, July, and August, 1892.

During June, July, and August thunderstorms occurred on forty-eight days in the various portions of the State. For the northern section of the State forecasts for this class of storms were issued from Cleveland on twenty-two days, and all were verified by the occurrence of storms in some portion of the section; thunderstorms were reported on twenty-four days for which no forecasts were issued. For the southern section of the State forecasts were issued from Cincinnati on ten days, and were all verified; thunderstorms occurred on thirty-two days for which no forecasts were issued. For the central section of the State, covering a radius of 50 miles around Columbus, warnings were issued on thirty-three days, of which thirty-one were verified and two not verified.

The above warnings were issued and based on the morning daily weather charts of the three stations. In addition to these, warnings were issued from Columbus based on telegrams received from Cincinnati, Louisville, and Indianapolis on five days, and of these two were verified and three not verified. Within the Columbus district seven thunderstorms occurred for which no warnings were issued. The percentage at these three forecasting stations, in the forecasts issued from the daily weather map, is very good, considering the limited knowledge as to the circumstances under which this class of storms develop.

No date for which the probability of the occurrence of these storms was forecasted occurred without the happening of the condition in some portion of the section. The great drawback to this excellent record is the simple fact that thunderstorms occurred on so many days for which no forecasts were issued.

I have the honor to submit the following conclusions which I have drawn from the charts made for this season, which I submit only as inferences, which may or may not be supported by the work of future seasons.

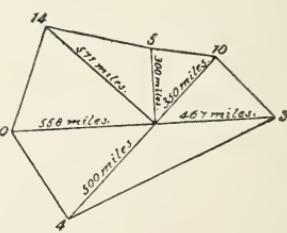
1st. *Movement of thunderstorms across the State.*—Thunderstorms appearing over the northwest portion of the State during the season have either moved to the northeast over the counties adjoining the lake or have taken a southerly trend to the southward of the northern watershed over the Scioto and Muskingum valleys and passed south-

easterly into West Virginia. Those appearing over the central-western border have moved east to the central portion of the State, and thence northeast to the Lakes or southeast over the Muskingum Valley to West Virginia. Those appearing over the southwest border have moved east along the Ohio Valley or dissipated. Those starting over the south-central portion of the State have moved northeast along the Ohio or southeast into West Virginia.

Of the various storms 46 per cent have moved to the southeast; 25 per cent to the northeast; 29 per cent to the east. The general trend of all well-developed storms appears to be to the southeast, over the central portion of the State, and is due, I should think, to the general contour of the southern portion of the State, the heated atmosphere of the numerous valleys therein, and the easterly movement of the surface air. The high elevation of the central-eastern and northeastern portions of the State exerts a more or less perceptible influence towards warding off the local storms to the southeast.

During the month of June the average velocity of the storms moving to the southeast was 25 miles; northeast, 26 miles; and east, one storm, 42 miles. During July, southeast, 32 miles; northeast, 17 miles, and east, 25 miles. During August, southeast, 32 miles; northeast, 36 miles. The average movement for all storms during June was 28 miles; July, 22 miles; August, 29 miles; and for the season, 26 miles. The greatest development and spread of any single storm was on August 9, when the electrical display was noted at two points 40 miles apart in twenty minutes, the least rapid occurred on June 27, when a rate of 10 miles was recorded.

2d. *Positions of low areas when thunderstorms occurred.*—During the month of June the centers of general storm areas were distant from the State in an average number of miles as follows: NW., eight days, 500 miles; W., four days, 500 miles; SW., one day, 400 miles; NE., six days, 400 miles; N., one day, 100 miles, and E., one day, 500 miles. During July, as follows: NW., three days, 700 miles; W., five days, 600 miles; NE., two days, 450 miles, and N., two days, 450 miles. During August, as follows: NW., three days, 430 miles; W., one day, 300 miles; SW., three days, 530 miles; NE., two days, 170 miles, and N., one day, 400 miles.



The above diagram is intended to illustrate the position of the low areas relative to the State of Ohio on the days on which thunderstorms occurred within the State. The outside figures being the number of days on which thunderstorms occurred in the different relative positions of the low area, and the inside figures the average number of miles the low areas were distant when they occurred. From

the diagram it can be readily seen that the thunderstorms occurred the greatest number of times when the low area was in the northwest, and it will be noted that they could be anticipated when the main storm was 900 miles distant, with a recurrence from day to day, as long as the main low area maintained a position to the west or northwest. Over 50 per cent of these storms occurred with the low areas in this position as regards Ohio. The next most frequent direction was when the main storm had attained a northeasterly direction as regards the State, and in the main appears to have been caused by the changes in temperature that accompany the passage of a large storm, the thunderstorms being mainly light and local in character and moving toward the southeast in advance of the general westerly or northwesterly winds. As shown by the diagrams, no thunderstorms occurred with the main low area to the south and southeast during the season. Whether the rule would hold that they do not originate with the low areas in the southeast quadrant remains for future work to disclose. Thunderstorms of July 11, 24, and 30 are phenomenal in movement, and unexplainable unless caused by a retrogression of thunderstorm energy.

3d. *Predictions of thunderstorms based on telegrams and upon the daily weather map.*—In regard to the successful prediction of thunderstorms, based upon telegrams received from points to the west and southwest, issued to points over the State in advance of the thunderstorms, I do not think it worth the expense involved. It is almost an impossibility to make a direct prediction as to the time and place with the information obtained in this manner. The movements of the different storms vary so greatly as to direction and velocity that a successful prediction is due more to chance than anything else. Predictions issued upon the daily weather map in the form of "probabilities" without any specification as to time or place, except the day and section, are far more applicable, and, with the limited knowledge at hand, successful, than the former class. This is most thoroughly evidenced by the record of the past season. While it might be profitable, if available, to use the telephone in tracing these storms across the State, still the warnings given in advance would be of such short time that no preparation to meet the exigency could be made. With the issuance of the "probabilities" and their diffusion over the State, the person interested, knowing that local storms of this character were anticipated, could so conduct his work as to protect himself from any serious loss.

I do not think the time has come for more definite forecasts than are at present given. The predictor, knowing the local peculiarities, the average path of development of the thunderstorms under a general set of conditions, and the general conditions, can make with a great deal of certainty his local forecast for his section, and be sure

to make a fairly good percentage. The success will, however, depend in a great degree upon the ability of the forecaster, individually, to grasp all the points bearing on his section, and to state them in as few words as possible.

Hoping that I have covered the ground as desired, and as fully reviewed the season as necessary, I remain,

Very respectfully,

CHAS. M. STRONG,
Observer Weather Bureau.

CHIEF OF THE WEATHER BUREAU,

Washington, D. C.

Chart I. Air Pressure and Temperature at 8 a. m., June 7, 1892, with Thunderstorms of same Date.

Form 106 F

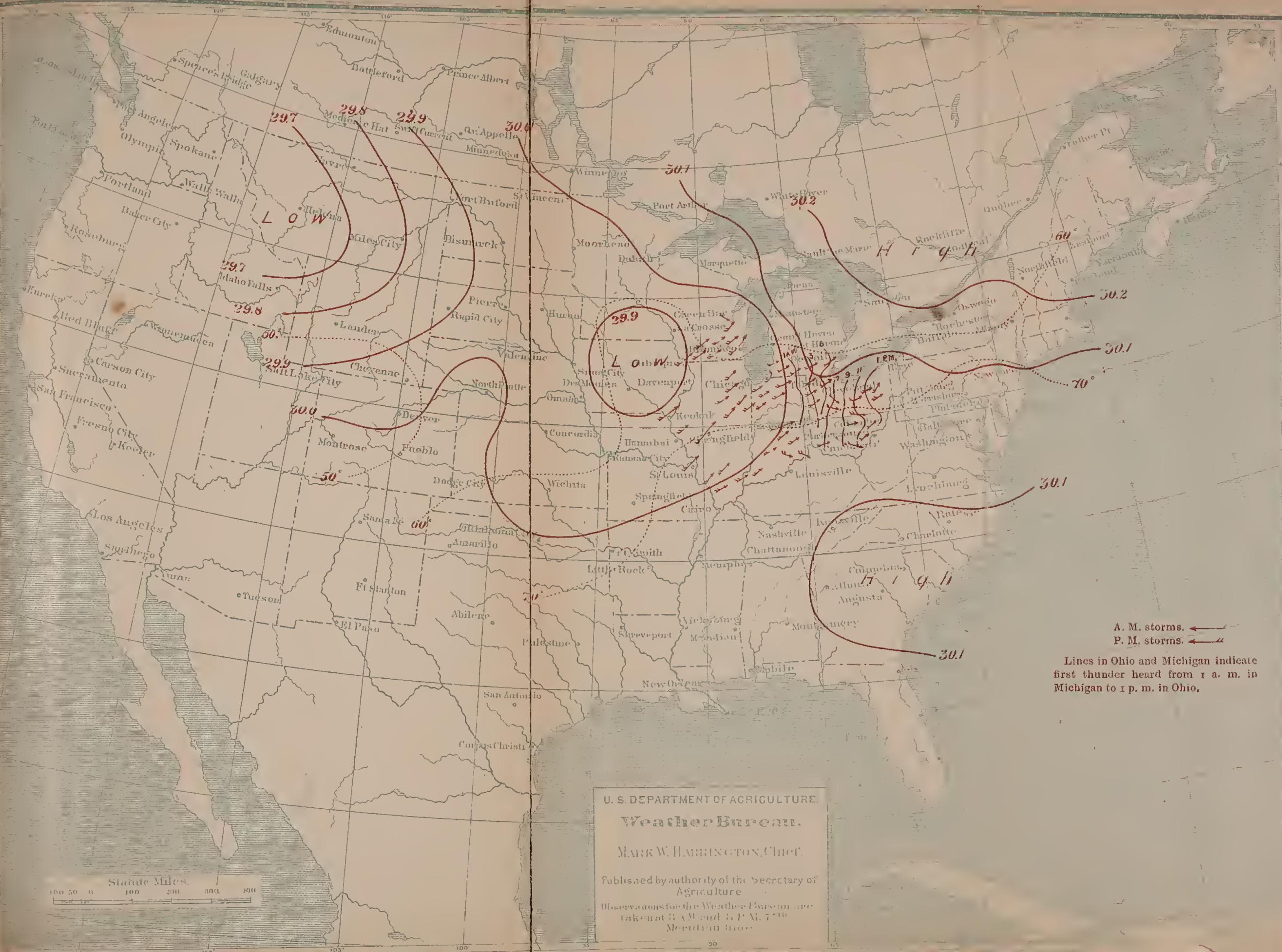


Chart II. Air Pressure and Temperature at 8 a. m., June 16, 1892, with Thunderstorms of same Date.

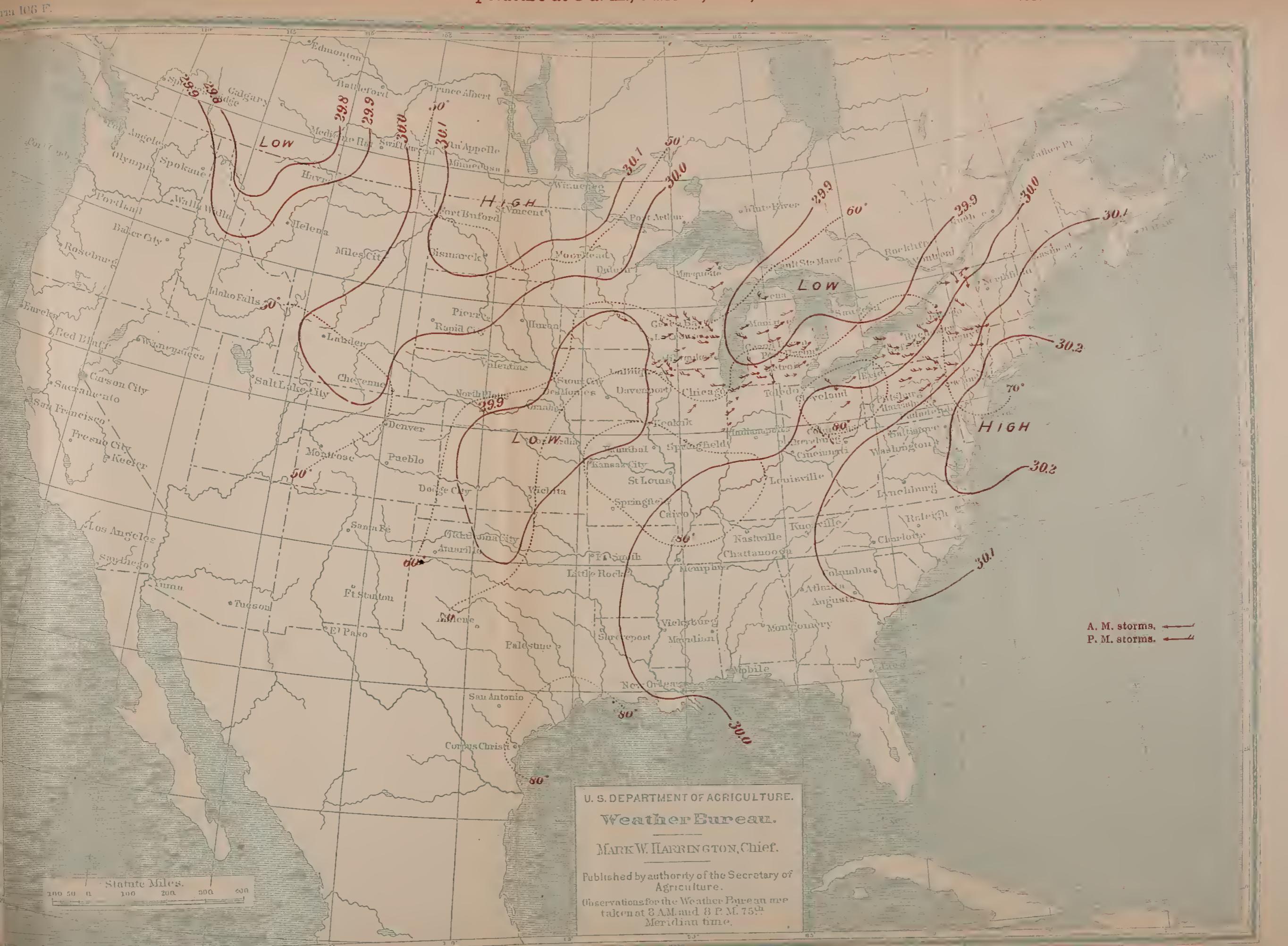
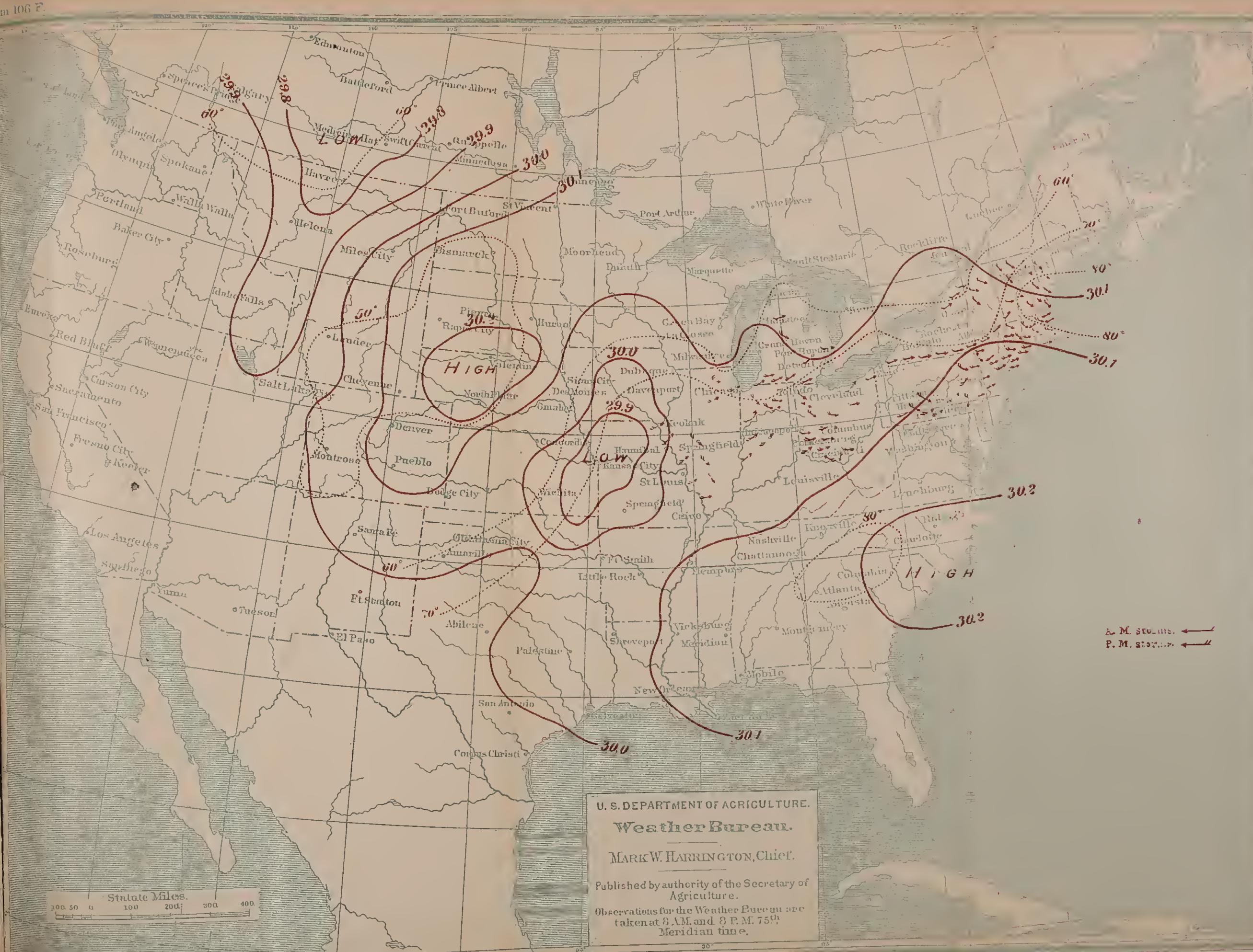


Chart III. Air Pressure and Temperature at 8 a. m., June 17, 1892, with Thunderstorms of same Date.



U. S. DEPARTMENT OF AGRICULTURE

Weather Bureau

MARK W. HARRINGTON, Chief

Published by authority of the Secretary of
Agriculture.

Observations for the Weather Bureau at

taken at 8 A.M. and 8 P.M. 75th
Meridian time.

Δ M. students. ←
P. M. students. ←



Chart IV. Air Pressure and Temperature at 8 a. m., July 15, 1892, with Thunderstorms of same Date.

Form 106 F.



Chart V. Air Pressure and Temperature at 8 a. m., July 16, 1892, with Thunderstorms of same Date.

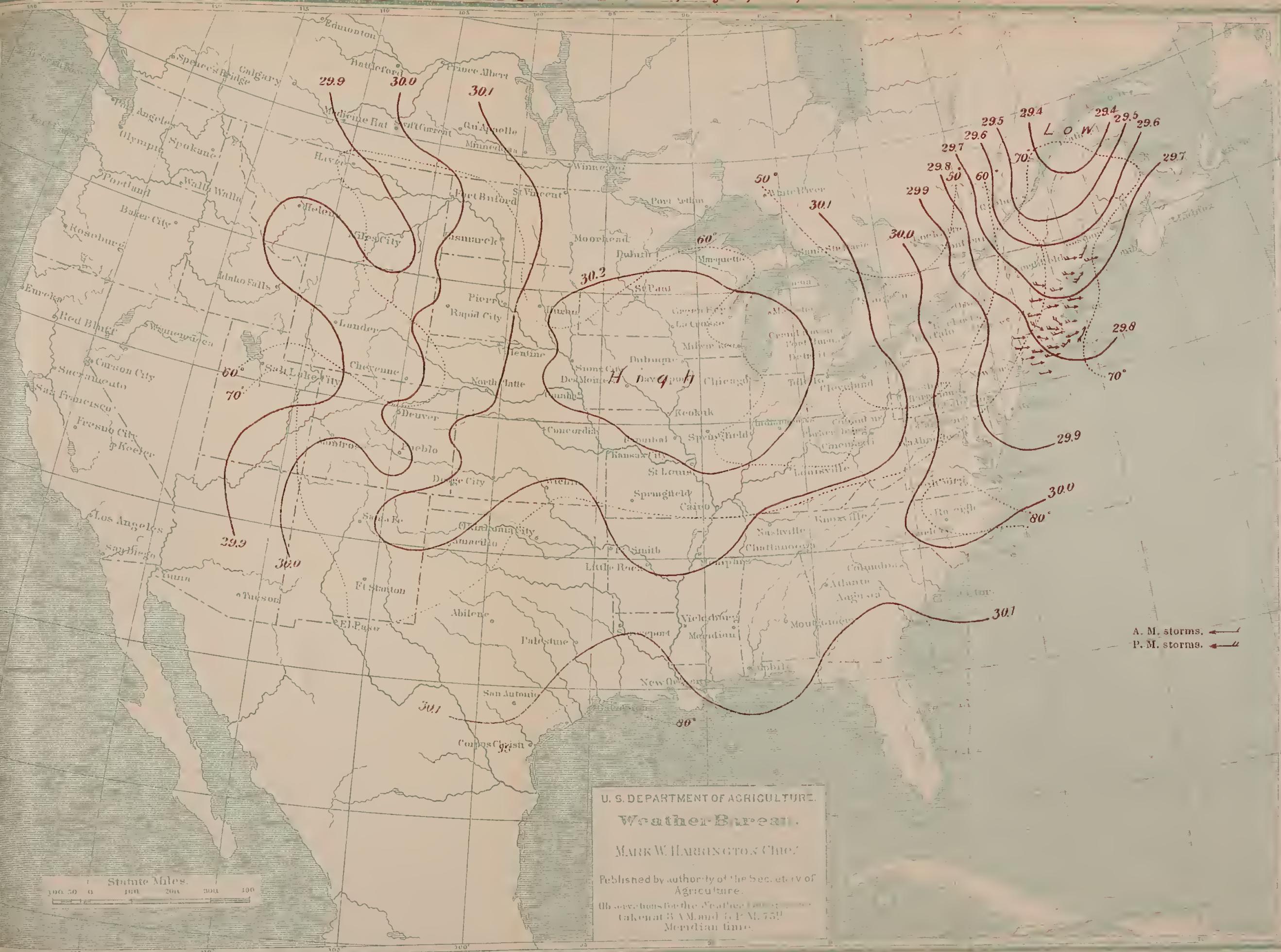


Chart VI. Air Pressure and Temperature at 8 a. m., July 26, 1892, with Thunderstorms of same Date.

